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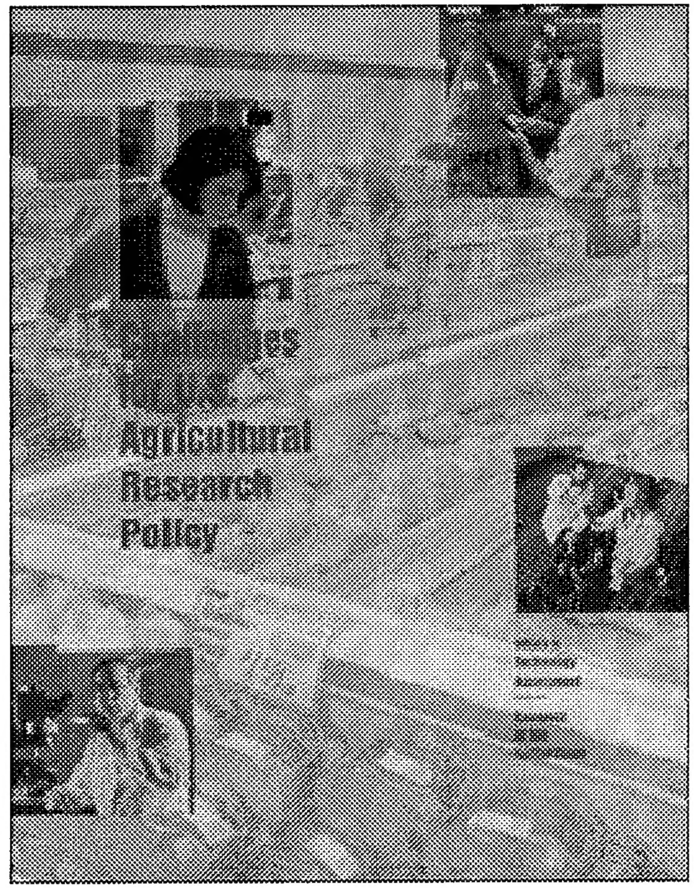

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Foreword

Agricultural productivity has increased markedly in recent years—more rapidly, in fact, than productivity in the overall U.S. economy. Many attribute a large part of this growth to public sector agricultural research, which is carried out primarily by land grant universities and the U.S. Department of Agriculture's research agencies. Despite this success, however, new budget constraints, scientific advances, and public demands for environmental safety are presenting the agricultural research system with the greatest challenges it has faced since its inception, more than a century ago. Questions have been raised about whether the old research institutions are still useful, and about how they should adapt to accommodate the new realities of the 1990s.

In discussions leading up to the 1995 farm bill, agricultural research policy has been put squarely on the negotiating table. Policymakers have been particularly interested in how well the agricultural system has responded to legislative directives in the past farm bill that called for a clarification of the purposes of agricultural research and extension, a national competitive research initiative, a sustainable agricultural research program, and research efforts to create new agricultural crops and new uses for agricultural commodities.

This report responds to a bipartisan request from the Senate Committee on Agriculture, Nutrition, and Forestry to determine the progress the research system has made in meeting the objectives set forth in these new areas, and to provide guidance on the management of agricultural research. In doing so, the report focuses on new ways to finance, organize, and manage agricultural research to prepare the system for the challenges of the next century.

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The past decade has brought substantial new pressures to bear on U.S. agricultural research. As science has opened the door to heretofore inconceivable advances, the agricultural research community has broadened its scope from devising new farm production technology to the full realm of agricultural activity—from the time the raw product leaves the farm to the final product in the consumer's home. Further, U.S. society has demanded that the research system expand its focus from increasing agricultural productivity, profitability, and competitiveness to addressing the impacts of agricultural production on the external environment. Of greatest concern have been problems such as water and air quality, nutritional quality, food safety, waste from food production activities, and the economic and social vitality of rural communities. The combination of these pressures has led to considerable change, and demands for continuing change, in agricultural research.

Clearly, more and better research is needed to address these issues adequately. A crucial determination is where and by whom that research should be done. By nature, the public and private sectors conduct very different types of research. Research that creates easily transferable information is more likely to be conducted by the public sector; research that creates information that is proprietary or embedded in a product is more likely to be conducted by the private sector. For example, the public sector develops pure lines and self-pollinated crop varieties that can be used by any seed company, while the private sector develops hybrid varieties proprietary to private firms that must be purchased annually by farmers if they are to be productive. Further, and perhaps more important, if the private sector determines that some research benefits (or costs) accrue to people other than those who use the results, it cannot capture the full returns on its investment, and most likely will not invest sufficiently in such research. The public sector must fill the gap.

Given the ever-greater demands on public agricultural research, however, filling the gap has become increasingly difficult. Very simply, the demand for such research has exceeded the supply available. An effective national strategy, and advances in science and technology of a scale and scope the system has not previously experienced, will be essential in the coming years.

In 1990, Congress became increasingly aware of the changing environment in which agricul-

tural research would be conducted and the need for the focus and scope of agricultural research to change. Accordingly, Congress revised the research title of the Food, Agriculture, Conservation and Trade Act of 1990 (FACTA). Specifically, Congress added major sections to the research title of FACTA on 1) purposes of agricultural research and extension, 2) a national competitive research initiative, 3) sustainable agricultural research, and 4) new crops, products, and uses research.

This study focuses on how the U.S. Department of Agriculture (USDA) has implemented the four new sections of the research title. This chapter includes a brief overview of the U.S. agricultural research and extension system, plus a summary of findings and policy implications for the above four components of the research title. In addition, potential changes in the financing, organizing, and managing of agricultural research are considered. Subsequent chapters treat these topics in greater detail.

U.S. AGRICULTURAL RESEARCH AND EXTENSION SYSTEM

The U.S. public sector agricultural research system, a dual federal/state system, came into being in the 1860s. It was not until the late 19th century, however, that the system began to provide the scientific knowledge needed to deal with the problems of agricultural development. Today, the federal agricultural research system includes the USDA's Agricultural Research Service (ARS), Economic Research Service (ERS), and Forest Service (FS); and the partner State Agricultural Experiment Stations (SAES) located within the Land Grant University System.

ARS, established in 1953, is USDA's largest intramural research agency. It has major responsibilities for conducting basic and applied research in natural resources, plant science, animal science, commodity conversion and delivery, human nutrition, and integration of systems. ARS employs approximately 2,670 scientists and engineers (of which about 2,500 have doctoral degrees) and had a FY 1994 research budget of $679.2 million. Research is conducted at approximately 100 domestic and seven foreign locations. Five major regional research centers are located in Maryland, Pennsylvania, Illinois, Louisiana, and California. ARS has cooperative research agreements with other USDA agencies, and many of the ARS facilities are located at or near academic institutions. Some ARS staff hold adjunct faculty appointments and participate in graduate teaching (30).

ERS was established in 1961 to provide economic and other social science information and analysis for improving the performance of agriculture and enhancing the economic and social vitality of rural America. ERS collects and maintains a number of historical data series on farm type, size, and number; production and input levels; trade; effects of farm policy; and socioeconomic characteristics of rural areas of the United States. ERS also performs statistical and analytical research, and is organized into four divisions covering commercial agriculture, food and consumer economics, natural resources and environment, and rural economy. ERS has limited funds to contract for research in the academic sector but is not authorized to administer a competitive grants program. The ERS budget for FY 1994 was $55.2 million (30).

The FS is responsible for research on the nation's forests and for technologies useful in the manufacture of pulp and wood-based products. Research topics cover a broad range. The FS also manages 182 million acres of forest. Its research budget for FY 1994 was $193.1 million. Much of the research is conducted through its intramural program and the federal forest experiment stations (30).

The Land Grant University System was established in 1862 by the Morrill Act. There was a need to provide higher education to the masses, with particular emphasis on the children of farmers and industrial workers. The Morrill Act made grants of land to states that were willing to create universities to fulfill this mission. Originally, education focused on agriculture and the mechanical arts, but the focus has expanded to include all of the major disciplinary fields.

The partnership between the state and federal government was extended to agricultural research with the Hatch Act of 1887, which provided federal funding for the support of agricultural experiment stations at land grant universities. Agricultural science had previously been the domain of innovative farmers, inventors, and the industrial sector, and progress had come primarily in the form of mechanical technology. Few states had provided significant funding for agricultural research. Eventually, however, agricultural output did not keep up with demand and food prices began to rise, leading to the passage of the Hatch Act. Nonetheless, it was not until the 1920s that the land grant system was fully functional. Today, there are 57 SAES located in each of the 50 states, the District of Columbia, the Pacific Territories (American Samoa, Guam, Micronesia, and the Northern Mariana Islands), the U.S. Virgin Islands, and Puerto Rico. Six historically black universities (the 1890 universities) and the Tuskegee Institute also conduct publicly supported agricultural research.

The Hatch Act provides research funding to states based on a formula that considers the importance of the agricultural sector to the state's economy. The formula funding system provides stable funding for research programs that may have long gestation periods. All formula funds must be matched by the state. The current formula for funding designates 1955 as the base year and the minimum amount to be allocated.

The federal share of Hatch and related funds (like the special grants described below) was \$317.5 million for FY 1993, compared with \$331 million in other federal funds (such as USDA's competitive grants program and other federal agency funds) and \$1376.3 million of state (\$985.4 million), industry and sales (\$256.1 million) funds (30).

The structure of the current system was completed with the passage of the Smith-Lever Act in 1914, creating the Cooperative Extension Service (CES), which directly provides farmers with useful information gleaned from the research system. Funding is provided to the states through a formula somewhat similar to that of the Hatch Act. Today, there are extension offices in nearly every county in the United States. They employ approximately 9,650 county agents and 4,650 scientific and technical specialists. The total CES budget is about \$1.2 billion annually. Of that total in 1993, the states provided almost half the extension funding (46 percent), the federal government about a third (31 percent), and the counties about a fifth (19 percent) (1).

The research system must have public support and funding to function. It also must have the flexibility and the management capacity to reallocate scarce resources to new priorities, and to attract highly qualified personnel who can keep abreast of changing technological opportunities. Despite high social returns to public sector agricultural investments, the system has been the subject of criticism from internal and external sources. External critics decry the heavy research emphasis on agricultural productivity and the lack of research devoted to nutrition and food safety, rural problems, and environmental concerns. Criticisms have been directed at the perceived low quality of the research, the inadequate interaction of agricultural researchers with the basic scientific disciplines that underlie agriculture, and the limited role of peer evaluation in project formulation and review. In addition, public-sector budget constraints have frozen funding.

The public-sector agricultural research system is clearly being challenged from many directions. Whether the system can be revitalized and renew its historical commitment to solve the problems of U.S. society, or whether it becomes isolated and loses its credibility with the public remains to be seen. The remainder of this decade will be a period of significant stress and change within the agricultural research system.

THE CHANGING ENVIRONMENT FOR AGRICULTURAL RESEARCH

As a catalyst to this change, internal and external pressures on the system will alter the function and structure of the system. Changing political support, resource base, and institutional frameworks will put pressure on the system to change (20,27).

Political Environment

Historically, political support for the agricultural research and extension system has come primarily from the farm and rural population; as a result, the system has placed heavy emphasis on increasing agricultural productivity. However, agriculture's traditional base of support has been eroding steadily. Farm numbers and populations have been declining, and today more than 75 percent of the total U.S. population resides in metropolitan areas. Of the 435 members of the House of Representatives, fewer than 100 represent rural districts (27).

Public interest groups have become increasingly critical of the emphasis on productivity in agricultural research. The books *Silent Spring* and *Hard Tomatoes, Hard Times* criticized the system for its failure to address the problems of the environment, rural communities, and consumer needs. Environmental, consumer, and animal welfare groups have become increasingly active in recent farm bill debates. Additionally, these groups have challenged the universities themselves by bringing lawsuits on the use of public funds for productivity-increasing research. A lawsuit was brought against the University of California system, as an example, for using public money to develop a mechanical tomato harvester.

Increased public activism is indeed changing the climate in which the agricultural system conducts research. As a consequence, the Food Security Act of 1985 contained several conservation measures, and many more such measures were added in FACTA. Several environmentally oriented research initiatives, such as the groundwater initiative and the low-input sustainable agricultural initiative (LISA), were also passed. In addition, new institutions were established to focus on research and technology transfer assistance for developing new crops and new uses for traditional crops. Congress has specifically directed agricultural research funds to key areas to help the system adjust to these new priorities faster (21).

Resource Base

Although total research funding has increased slightly over the past decade, agricultural research is generally underfunded when one takes into account its high rates of return on investment (see Chapter 6). For example, the states provide the majority of the funding for research at the SAES, and through the 1980s, state support increased. However, the recession of the early 1990s has constrained state budgets, resulting in few increases and in some cases declining state support for agricultural research.

USDA both disperses and consumes federal research funds. ARS accounts for about one-third of USDA research and extension expenditures, a share that has remained fairly constant over the years. Most of USDA's funds are spent on intramural research by ARS, ERS, and FS. Slightly more than a fifth of these resources are administered by the Cooperative Research, Education, and Extension Service (CREES). Most CREES funds go to SAES and other cooperating institutions.

USDA is SAES' second-largest single source of research funding. Historically, USDA funding has been in the form of block grant formula funds. Decisions about how these funds are allocated have been made at the local level. USDA funding has basically stagnated and barely keeps up with inflation. Increases in USDA funding primarily reflect congressional earmarking of grants for such concerns as water quality, nutrition, and integrated pest management and biological control research.

Research funds are not evenly distributed to all experiment stations. The experiment stations in 12 states (California, Florida, Iowa, Illinois,

Indiana, Michigan, Minnesota, North Carolina, Nebraska, New York, Texas, Wisconsin) account for nearly 50 percent of the total research funding available to SAES, nearly 70 percent of the USDA competitive grants, 61 percent of all competitive funds obtained from federal agencies other than USDA, and nearly 60 percent of all funding from industry support and product sales. All SAES have diversified their funding sources to some degree. However, the "have not" SAES rely primarily on traditional sources of funding (state and USDA formula funds), while the "haves" have to a greater degree diversified their funding sources (27).

Technology Base

To continue doing high-level research, universities and federal laboratories need to keep abreast of new information and technologies. New biotechnologies and information technologies in particular are yielding powerful research tools that can be applied to questions in a wide range of scientific disciplines. Effective use of these technologies will require new funding, or a reallocation of funding from traditional research projects. The scientists who use these new research tools will need a thorough grounding in the basic scientific disciplines that underlie biotechnology and information technology.

The same 12 SAES that receive most agricultural research funds also receive most of the resources devoted to biotechnology research. Indeed, the concentration of resources in only a few experiment stations is even more pronounced for biotechnology than for all agricultural research.

Legal Environment

The legal environment in which the agricultural system operates is changing. Congress has for the past 60 years expressly permitted intellectual property protection of new plants. In 1980, the U.S. Patent and Trademarks Office changed its interpretation of patent laws so that microorganisms and animals can be patented as well. More recent patent and trademark amendments gave universities, other nonprofit organizations, and small businesses the option, with few exceptions, to retain the title rights to any federally funded inventions that they developed.

Until recently, only a few institutions aggressively marketed the research of their faculties, primarily by licensing their technology to the private sector. Now, however, venture capital pools, technology development companies, and research companies with the goal of transferring technology and making money have become much more common. In addition, some universities now hold equity in or are otherwise involved with new ventures that invest in and commercialize the new technologies developed. These relationships between universities and the private sector, which are rapidly becoming more common, facilitate technology transfer, further beneficial relationships with private companies (sometimes with the goal of securing more research funding for the institution), and provide a way to better acquaint researchers with the practical application of their research results and with real-world problems. Researchers who create the new technology are now often given a share of the returns. Given these realities, conflict-of-interest policies have been designed to help ensure that intellectual property stemming from publicly funded research remains available to the public. Whether such policies are adequate is a central question, but they are becoming common throughout the university research system (21).

This wide range of changes was in part what led Congress to amend the research title of FACTA in 1990. USDA's efforts to implement the sections added to FACTA are discussed below.

CONCLUSIONS

Purposes of Agricultural Research and Extension

Background

In FACTA, Congress specified the purposes of agricultural research and extension: 1) to con-

tinue to satisfy human food and fiber needs; 2) to enhance the long-term viability and competitiveness of the food production and agricultural system of the United States within the global economy; 3) to expand economic opportunities in rural America and enhance the quality of life for farmers, rural citizens, and society as a whole; 4) to improve the productivity of the American agricultural system and develop new agricultural crops and new uses for agricultural commodities; 5) to develop information and systems to enhance the environment and the natural resource base upon which a sustainable agricultural economy depends; and 6) to enhance human health.

These purposes not only emphasize agricultural sustainability and rural social and economic concerns—they embrace the entirety of the agriculture, food, environment system. They emphasize major contemporary issues such as the environment and natural resources, economic and quality of life issues for rural America, new crops and new uses, competitiveness of the agricultural system, and human health. Ultimately, they lead to accountability. Unfortunately, even though these purposes provide overall guidance to USDA for research, they have not been implemented in any direct way.

Findings and Policy Implications

The Secretary of Agriculture has not established guidelines for USDA overall, and individual research units have not established guidelines for their programs.
Given Congressional interest in purposes, and the value of being clear about them, a set of core purposes needs to be adopted by USDA for its research and extension programs. The purposes should be implemented through a set of guidelines and operating principles for program planning, priority-setting, and management, funding, and evaluation. One way of establishing purposes is to adopt the purposes established in FACTA throughout USDA.

Although the FACTA purposes are straightforward and appropriate, some other definitions of research purposes have emerged. The Congressional purposes might be considered in light of these other definitions. Alternatively, USDA could bring the several initiatives for purposes together into a unified whole. It need not, and should not, frustrate or obscure Congressional intent.

A common failing with purposes is that they often are so general as to have little meaning.
Purposes should be focused and precise, so that they can provide meaningful guidance for implementation. One approach is to focus on key contemporary national issues—the central feature of the Congressional purposes in FACTA. This approach has the advantage of focusing attention on issues for which research and extension can be expected to make a major difference. As such, measurable objectives and specific management actions and evaluations can be set forth.

Alternatively, USDA could provide support for generic research advancement across the wide spectrum of research and application for the agriculture/food/environment sector. This approach has the advantage of ensuring that the entire research system for the sector is supported and incorporated into planning, allocations, and evaluations. It has the distinct disadvantage of eschewing focus on pressing national issues and of being substantially featureless as to priorities and direction.

USDA should decide whether to engage in a strategic and operational planning approach for focusing on key national issues.
"Unified strategic research and applications/extension plans" for key contemporary issues of major national interest could be employed. The intent is to integrate all potential and actual participants into a unified strategy for addressing issues so as to make as rapid progress as possible through coordination and integrated planning. The present system has a low degree of coordination and integrated planning. The situation is discussed further in the next section on the National Research Initiative Competitive Grants Program, which would have to be one of the agencies participating in such plans.

USDA should determine how best to engage the research agencies in addressing purposes and implementing them.

At this writing, each agency determines how to implement purposes and with whom to relate. This approach has the advantage of being "inner-directed." It has the disadvantage of not necessarily securing the advantages that could (and likely would) accrue from collaborative work.

Alternatively, an integrated approach could be established among the agencies. Such an approach would have the advantages of ensuring that the best and most efficacious expertise and capacity are taken from each agency and woven into a coherent whole. Further, this approach involves all participants, which could lead to efficiencies and synergisms that might not otherwise exist. It has the disadvantage of being potentially cumbersome, diminishing long-standing autonomy, and leading to clashes among different institutional cultures.

USDA must give more emphasis to after-the-fact evaluations.

Virtually all emphasis is currently on planning specific categories of research and deciding how to aggregate resources to do the work. This approach is not sufficient. In recent years, national operational planning, which sets measurable objectives for key national issues, has become more popular. This is significant progress and demonstrates that operational planning can be done effectively. However, there has not been similar progress in outcomes evaluations, both to determine progress in achieving the objectives and as a guide for future program activity and also resource allocations.

The current system could be transformed to include after-the-fact evaluations of outcomes and impacts. Adopting such evaluations would continue the evolution of management of the system, be consistent with increased funding stringency and for improved performance of government effectiveness, and be a significant advance in adding key factors for allocating resources. It would, ideally, involve programmatic outcomes and impacts and also evaluation of management and operational effectiveness and of financial outlays.

National Research Initiative Competitive Grants Program (NRICGP)

Background

By authorizing the NRICGP in FACTA, Congress reaffirmed its commitment to funding research for foundational knowledge (that is, knowledge used as a basis for more advanced and applied research) through grants that are initiated by researchers themselves, peer-reviewed, and competitively awarded. Congress significantly expanded the authorization for funding competitive grants, specified six high-priority research areas, strengthened the peer-review and advisory oversight of the program, and authorized funds for multidisciplinary research.

Overall, the NRICGP has been implemented effectively. The priority research areas are appropriate and have received emphasis and funding within the constraints available. A number of steps, including advisory mechanisms, have been taken to ensure that the program is relevant to issues in the agriculture/food/environment sector. However, appropriations have been substantially less than authorized and required for adequate funding of the priority research areas. This dearth of appropriations has necessarily led to inadequate funding of key research areas, including natural resources, environment, and rural economic vitality. Notwithstanding the success of the program and its continuing promise and potential, there are a number of major implementation and funding issues and policies that should be dealt with during the next five years.

Findings and Policy Implications

USDA should reinforce the focus and emphasis of the NRICGP.

The focus and emphasis of the NRICGP are on increasing foundational knowledge through grants that are competitively awarded. The grants are based on peer review, using the criteria of scientific quality and relevance to the long-term sustainability of the agriculture/food/environ-

ment sector. At the same time, pressure to engage the NRICGP directly with the applied aspects of contemporary issues could well divert the NRICGP from its original purpose.

If the current emphasis is maintained, the original intentions for the program are preserved. The NRICGP has shown that it is capable of discerning which topics are relevant and suit the needs of foundational research knowledge. This capability increases the attractiveness of USDA's mission for agriculture/food/environment to all the nation's scientists, a desirable national policy goal.

Alternatively, the NRICGP could be opened to more applied research. Such an action would significantly dilute, and ultimately likely preclude, the program focus for doing the kind of foundational research that needs to be done. It would also make the NRICGP just another funding vehicle for all manner of research already well represented in USDA's research portfolio. Should this happen, it would be reasonable to consider phasing out the entire NRICGP.

USDA should affirm and reemphasize the direction of the NRICGP on foundational knowledge.

The NRICGP has been asked, by direction and by funding actions, to focus on a broad array of research questions, priorities, and types. It must direct its efforts to fundamental and related mission-linked research to provide foundational knowledge for the agriculture/food/environment sector, including major long-term issues such as sustainable agriculture and water quality; and more specific topical issues, such as global change and monitoring for UV-B radiation.

The program has responded well to this mixture of demands and has, in the main, been faithful to its original intent. Because of earmarking and other stresses on the NRICGP, its efforts have, however, involved sacrificing some funds and responsiveness.

Consideration could be given to formally identifying the areas where foundational knowledge is needed and incorporating them into the NRICGP. Virtually every issue requires additional foundational knowledge. This appropriately falls within the NRICGP, and it is reasonable that the program be considered as the agency which should support it (but only if additional funds are provided for new programs and topics).

USDA should develop unified strategic research and application/extension implementation plans for contemporary issues.

The various programs and agencies that make up USDA's research portfolio operate independently from one another to a large extent, even though the programmatic issues that undergird and animate the program are common to all. Further, programs such as the NRICGP (along with major portions of the ARS and the SAES system) emphasize foundational knowledge, common to a number of the programmatic emphases and agency priorities. A set of unified strategic research and application/extension implementation plans for key contemporary issues would help to ensure that the necessary work gets done, related elements are coordinated with each other, and application of research results is focused and coordinated.

There are no such strategic plans at present. Continuing to operate without them means that the present system of agency autonomy and the current coordination system among the federal elements and among the federal, state, and private sector partners would suffice for addressing the issues. The current system has the virtue of avoiding undue centralization; it has the drawback of being largely uncoordinated and responsive only to the interests of the individual elements.

Increasing coordination among programs and agencies without formally creating such unified strategic plans is an alternative. This approach would use the current systems and would avoid creating yet more planning and associated institutional mechanisms. Some observers believe there is already more planning than necessary.

Creating a pilot or full program for such unified plans could be attempted. A pilot program

could focus on selected key topics such as water quality, pest management, and sustainable agriculture. To make the program work (and make it attractive to the participants), planning could be followed by funding to implement the program. The risk is that the plans would be simple listings and recitations of work under way. That result in itself would be satisfactory if it were linked to desired outcomes, but would be unsatisfactory if merely the status quo were otherwise continued. The aim is to promote greater efficiency and effectiveness by leveraging and coordinating work and funding, and by being clear about and dedicated to securing meaningful outcomes within specified time periods.

The NRICGP is not funded sufficiently.

Appropriations for the NRICGP are currently about $100 million, even though the authorized level is $500 million. The availability of quality proposals is more than double the current funding level, and there is obvious programmatic need for foundational knowledge from the program. The return on research investments is high (20 percent or more). Without additional funding and continued growth of funding, there is every reason to believe that the program will languish at its current level, and that a major opportunity for securing both knowledge and researchers for the sector will be lost.

Earmarking and targeting NRICGP funds is counterproductive.

Incorporating earmarks and other targeting of NRICGP funds would continue current practice. Over time this practice will destroy the integrity, and ultimately the fabric, of the program: the demands for funding for major issues are so strong and pervasive that there is no obvious way to limit earmarks and targeting in a systematic way. Earmarks address applied issues that are the focus of other parts of the research portfolio, not the NRICGP. Most important, earmarks do not provide the foundational knowledge that the agricultural sector needs.

To ensure the integrity of the program, all earmarking and targeting should cease. If it is believed that the NRICGP is appropriate for doing some or all of the work on a topic, the program staff should be consulted to determine how the interests might be met *within the program structure* and what funding would be required. Responses to earmarks have shown that this would be effective.

Sustainable Agricultural Research and Extension

Background

Congress has been interested in sustainable agriculture since at least 1977, when it first defined the new phenomenon as an effort to: 1) satisfy human food and fiber needs; 2) enhance environmental quality and the natural resource base upon which the agriculture economy depends; 3) make the most efficient use of nonrenewable natural biological cycles and controls; 4) sustain the economic viability of farm operations; and 5) enhance the quality of life for farmers and society as a whole. Congress' interest grew out of a number of different but largely related concerns: emerging recognition that soil and water resources were being degraded; adverse environmental and human impacts of chemical pesticides; the steady decline of the economic and social vitality of the rural and farming sector; steadily decreasing farm numbers and growing evidence of increasing proportions of larger farming operations and part-time farmers; and increased competitiveness in agricultural production. Congress also aimed to address the unease of some observers who argued that these concerns had received only limited if any attention from USDA, or from the land-grant university and state agricultural research system. This issue was addressed further in the Food Security Act of 1985 (the 1985 farm bill) by Congress' intention that USDA determine how to do more research to preserve natural resources and environmental quality concurrent with ensuring agricultural productivity. Through FACTA, Congress went on to establish 1) the Sustainable Agriculture Research and Education (SARE) program and 2) more specific emphases for a

sustainable agricultural economy and for the natural resource, environmental, and social and economic quality of agriculture and the rural sector, by altering the research title.

Findings and Policy Implications

There is little effective leadership and management for sustainable agriculture in USDA.

A major criterion for the success of any program is that it be supported strongly and clearly by senior policy leadership, and that a management structure be established that is both effective internally and accountable externally. At present, such actions have not been taken, although a major initiative to this effect has recently been established, reporting directly to the Deputy Secretary.

USDA should determine the extent to which sustainable agriculture should receive emphasis, planning, management, and funding throughout the department on a *systemic* basis.

The critical issue is whether sustainable agriculture—or other major issue comparable in scale and substance—should receive *systemic* leadership, management, planning, funding, and oversight and accountability. Or, alternatively, whether such issues should receive attention based solely on the interests and perquisites of individual agencies and individuals. Advantages of the former include integration, efficiency, cost-effectiveness, and increased accountability for results. A particular advantage is that such an approach would provide for a systemic analysis of possibilities and encourage cross-boundary thinking and collaboration. Possible disadvantages include ineffective, possibly misdirected "top-down" leadership and management; insufficient scientist and extension motivation and commitment; and the possibility of catastrophic failure from "central planning" or its variants. An almost certain disadvantage is the lack of significant systemwide operational planning (in contrast to thematic and budget acquisition planning, which is done in USDA).

The advantages and disadvantages of the alternative approach are essentially the obverse of those of the systemic approach. Possible advantages include minimizing or even avoiding the disadvantages of the systemic approach. Possible disadvantages are lack of attention to and incomplete coverage of sustainable agriculture; lack of involvement of key partners; and cost-ineffectiveness and lack of research focus.

If the systemic approach is taken, a number of options can be considered. A useful option would be to build and expand on the current initiative. Another useful option would be to create an *integrated, unified strategic research and applications plan*, as outlined previously in the section on the NRICGP. If that option is pursued, most if not all of the disadvantages outlined above would be avoided.

Funding issues should be engaged.

There seems little reason to believe that sustainable agriculture will not benefit from steady increases in appropriations, as a consequence of the importance and priority for sustainable agriculture and of the success to date. However, if increased funding is to come, it will most likely be at the expense of another research area. Such an action would have its own limitations. For example, if the funding were taken from the NRICGP, a major venue for attracting scientists to the fundamental research questions that underlie sustainable agriculture would be destructively compromised.

Congress or USDA could redirect funds from the federal and state partners to be dedicated to sustainable agriculture. While such an action may be satisfactory for federal agencies, it will likely be resisted strongly, and successfully, by state partners, given past history. A more focused, incentive-based system seems more appropriate.

Redirection is most effectively and directly done through increasing the competitive grants programs for both the SARE and training programs. Given the constraints on formula funds and the decentralized traditions of allocating and using them, expanding the competitive grants in

these two programs is the more efficacious approach. Much national experience through the science and technology sector shows that focus and direction are easily and positively established for competitive grants, and proposals of highest merit and relevancy are most readily assured of being funded. Further, the current grant programs are successful to this point and give every indication of being so in the future.

Alternative Agricultural Research and Commercialization

Background

Through FACTA, Congress gave major attention to the broad topic of new uses and products for the first time. Its action reflected widespread national interest in diversifying the agricultural production sector beyond traditional commodities; expanding the economic vitality of the agricultural sector; and expediting technology transfer from the laboratory to commercial use.

Two major initiatives were taken by Congress: 1) establishment of a program and organizational structure for Alternative Agricultural Research and Commercialization (AARC) and 2) establishment of the Agricultural Science and Technology Review Board. AARC assists the commercialization of nontraditional, nonfood products through product development and prototyping, marketing and economic analysis, precommercial development, early-stage manufacturing and testing, and product introductions. Its emphasis is on precommercial development and testing, marketing, and pilot production, rather than on research and early-stage development. This is done because it is currently believed to be the most cost-efficient way of expediting commercialization. The major research function, appropriately, is left with public or private research and development agencies. Given that the focus is on business development and product commercialization, inherently private sector rather than public sector activities, such an emphasis is appropriate. AARC's central financial resource is a revolving fund initially provided by Congress to make investments to assist commercialization of new products. Repayment is through a percentage of future sales or equity in the company.

The Agricultural Science and Technology Review Board was established to provide technical assessment of agricultural issues and to consider the impact of technologies on agriculture and the social and economic well-being of communities. Like AARC, it complements Congress' intent in encouraging the development of technologies friendly to the environment, people, and communities. However, both of these new institutions have suffered from inadequate funding.

Findings and Policy Implications

Funding issues for AARC should be addressed.

By any measure, this program is a significant element in USDA's overall program, and a potentially significant adjunct to the department's constituent agencies. As such, its future needs to be addressed forthrightly, and commitment must be made to its success. A key element is funding. Based on the data available, and absent the ability at this point in time to make conclusive judgments about the efficacy of its financial investments, AARC's funding needs to be sustained at least at the present levels, and preferably increased substantially to add to and diversify the investment portfolio. With the right investments, the program should reap a profit that can be continuously reinvested in additional technologies and products.

If funding continues at current levels, it would mean appropriations of about \$8–10 million per year. Such appropriations would be fiscally prudent (and conservative), given the early stage of the program and the need for determining analytically the success of the project selections and investment decisions. However, this relatively low level of funding also indicates to the industry that AARC will "go slow"—even though there is evidence that the program is working well and could be of greater benefit and impact with additional funding.

As an alternative, the program could be expanded commensurate with current staff and project availability. At present, the program can be expanded by two- to four-fold without an evident decline in quality, according to staff analysis. Modest expansion of the appropriations to $15 million for FY 1996 and to $25–30 million over the following two years would be reasonable. This would bring the total in the revolving fund to a little less than $100 million.

USDA should determine the optimum location and functions for technology review and assessment.

At present, this important function rests with the Agricultural Science and Technology Review Board established by FACTA, which is outside the environment of the operating USDA agencies (e.g., ARS and ERS) and virtually an integral part of another advisory body (the Joint Council for Food and Agricultural Sciences). If close involvement between research and development and technology review and assessment is desirable, as seems appropriate for most circumstances, it is also appropriate that this review and assessment function be brought philosophically and operationally closer to the operating agencies. Alternatively, if review and assessment are to be something akin to a "conscience" for the operating agencies, it is reasonable to suggest that at least some of the function be done outside as at present, but also with input from, the operating agencies.

At a minimum, technology review and assessment must be emphasized throughout USDA. Without such emphasis, review and assessment will always be considered second-hand activities that are not directly important to the operating program units.

The present situation keeps the board in relative obscurity, without any real opportunity for interaction with the operating agencies. It does, however, provide opportunity for independent assessment.

Alternatively, the board could be folded into the Joint Council for Food and Agricultural Sciences. Such a plan has the virtue of administrative simplicity and connection of assessment to the review, oversight, and advisory functions of the council. It does not address the fundamental issue of disconnection from the operating agencies.

USDA should create technology review and assessment functions in each operating agency, and also create a significant coordination and collaboration function to work among them in a synergistic way.

The reasons for this approach are derived from the above rationale: importance, integration into operating units, coordination as appropriate with related units, and a USDA-wide approach.

Financing, Organizing, and Managing Agricultural Research

Background

Agricultural productivity has grown rapidly in the United States relative to productivity in the general economy. Many attribute a good portion of this growth to public-sector agricultural research and extension, which operates primarily through land-grant colleges and USDA research agencies, in a system that was introduced over a century ago. In recent years, the agricultural sciences have increasingly been asked to do more with less. Questions have been asked about whether the old research institutions are still needed, and about how they should adapt to accommodate changes in science, in scientific institutions, in society and social attitudes, in government, in agriculture itself, and in the general economy.

To achieve the greatest gains for society as a whole, a fundamental rethinking of the basis for and approaches towards *financing*, *organizing*, and *managing* public-sector agricultural research is needed. Most previous commentators have called for more federal dollars for research—but that is only a part of the solution. Other public policy mechanisms can (and should) be used, along with taxpayer funds, to increase the total private and public investment in agricultural research, and to promote a socially profitable

mixture of research programs (from basic to applied research; across disciplinary areas; across commodity-oriented research programs; in terms of its geographic relevance; and between environmental and other natural resource issues). The policy analysis must include a consideration of different funding mechanisms—how they affect the cost of research (including who bears the cost in relation to who benefits), and how they affect incentives for private research and development.

A rethinking of policy extends beyond the boundaries implied by the current institutional structure, dominated by the SAES and the USDA intramural laboratories. Such an effort means considering greater use of in-between alternatives, such as regional research institutions, and allowing open competition among all of the different institutions, where appropriate, for the available funds.

An integrated, rather than piecemeal, assessment of the full range of public policy issues related to agricultural research is required. Decisions must be made concerning 1) the relative responsibilities of the major research participants for research (for example, fundamental, applied, developmental; generic or specific; geographic emphasis; and the like); 2) the amount of resources (federal, state government, and other) to allocate to the research; 3) the way research is funded; 4) the types of research undertaken; 5) the institutional structures related to allocating resources and conducting research; 6) the mechanisms for communicating research results; and 7) the relative roles for the major participants including federal and state governments, universities and research institutes, and the private sector. All of these are mutually dependent, and they should be thought through together. Making changes in one element (for instance, increasing or decreasing federal support for research, or the responsibilities of state governments compared to the federal government for funding locally and regionally significant research) without thinking through the implications for other elements of the system (incentives and institutional mechanisms for industry-based research support, for instance) could have undesirable and unforeseen consequences.

Findings and Policy Implications

Economic efficiency should be stressed.

The rationale for intervention leads to a single criterion for designing public policy for agricultural research and for organizing and managing the institutions that are used to implement that policy—economic efficiency. This would permit the incorporation of externalities, such as environmental and social effects, into the evaluation of research funding. According to this criterion, the evidence suggests that the total (private plus public) investment in agricultural research should increase.

Alternative financing methods should be developed.

Financing can be made more efficient—in terms of total quantity of research resources, lower costs of raising the revenues, and greater allocative efficiency. As but one approach, increased use of industry check-off funds is a good way to do this. The development of this and comparable types of arrangements could be stimulated appropriately by the provision of tax incentives and matching grants from state and federal governments.

Alternative organizations for agricultural research should be created.

Research could be organized more efficiently by developing alternative institutions to bridge the gap between state and federal jurisdictions, and through greater use of economic efficiency criteria to determine the balance between different types of research organizations. The current system emphasizes two types of institutions (for example, SAES versus intramural USDA institutions) funded by a combination of state and federal government monies. There is a potential to develop new institutions serving subnational multistate regional or commodity interests, on the basis of efficient research jurisdictions, with a mix of private and public sector funding.

Management of agricultural research can be improved.

Finally, the management of research can be improved by substituting economic incentives for central directions, by clarifying the economic objective of research and ensuring that resources flow according to the achievement of that singular purpose, and by using competition rather than committees to allocate resources. To achieve the greatest social payoff from public-sector research, the current arrangements (formula funding and special grants for extramural research, and an earmarked pot for intramural research) must give way to a greater use of competitive grants.

Purposes of the Agricultural Research and Extension System 2

Congress has long evinced interest in the effectiveness of the agricultural research and extension system. It has placed particular stress on high-priority national issues that it has previously identified, and on securing research results and applications (outcomes) that address those issues. Accordingly, Congress took the strong step in FACTA of specifying purposes that "[f]ederally funded agricultural research and extension programs shall be designed to, among other things, accomplish...." These purposes are to:

1. "continue to satisfy human food and fiber needs;
2. enhance the long-term viability and competitiveness of the food production and agricultural system of the United States within the global economy;
3. expand economic opportunities in rural America and enhance the quality of life for farmers, rural citizens, and society as a whole;
4. improve the productivity of the American agricultural system and develop new agricultural crops and new uses for agricultural commodities;
5. develop information and systems to enhance the environment and the natural resource base upon which a sustainable agricultural economy depends; and
6. enhance human health:
   - by fostering the availability and affordability of a safe, wholesome, and nutritious food supply that meets the needs and preferences of the consumer; and
   - by assisting farmers and other rural residents in the detection and prevention of health and safety concerns."

In expressing these purposes, the Congress was also careful to note they are "[s]ubject to the varying conditions and needs of States."

Further, to encourage early implementation of the purposes, the Congressional conference managers stated their intention "that the Secretary establish guidelines to ensure that the purposes expressed. . .are reflected in the priority setting processes for research and extension programs such that projects consistent with these purposes are emphasized and each of these purposes is advanced by the research and extension program in its entirety...[emphasizing]...that it is not their intent that this statement of purposes be used to prohibit any research or line of inquiry."

Several observations about the FACTA purposes are in order. First, they emphasize agricul-

tural sustainability (both environmental and social) and rural social and economic concerns. This is a new emphasis for the farm bill and for the agricultural research system, even though sustainability has been intrinsic to a number of initiatives during the past 15 years (such as those concerning integrated pest management and water quality).

Second, the purposes embrace explicitly the entirety of the agriculture/food/environment[1] sector. This is a major departure from the previous single-minded emphasis on increasing agricultural production.

Third, the purposes focus on relevance by emphasizing several major contemporary issues in the agriculture/food/environment sector, including environmental and natural resources "upon which a *sustainable agricultural* [emphasis added] economy depends"; economic and quality-of-life issues for rural America; new crops and new uses in relation to productivity of the agricultural system; competitiveness of the food production and agricultural system; and human health, nutritious food, and prevention of health concerns. These issues are further emphasized by individual subtitles and sections of FACTA. For example, subtitle B addresses two central components of sustainable agriculture: sustainable use of environmental and natural resources, and the social and economic quality of life for rural communities. Subtitle G addresses new uses and products, and section 1605 establishes a technology assessment board to relate research results to technology transfer and application. Congress is clearly stressing its belief that federally funded agricultural research and extension programs should be concerned with the *entirety* of the agriculture/food/environmental sector, not just the agricultural production and productivity components.

Fourth, the purposes lead to accountability. Congress wants these purposes to be implemented *operationally* as rapidly and fully as possible throughout the federally funded agricultural system, including the state programs that receive federal funds such as the SAES and CE systems. This is illustrated by the conference managers' specific intention that the Secretary establish guidelines to make priorities consistent with the purposes and to emphasize projects consistent with the purposes. Taking the purposes and the guidelines together, it is reasonable to conclude that Congress is especially interested in seeing useful results from federally funded research, in ensuring that these results be applied to major issues, and in seeing that USDA is responsive to the directions and interests of Congress. In short, Congress wants USDA to be accountable.

Fifth, the context for focusing on purposes has expanded substantially since FACTA was passed. Purposes for the research program are emphasized in at least three additional actions. The Government Performance and Results Act (GPRA), designed to increase the effectiveness of the federal government, also involves research and hence the purposes for research. It further embodies the concepts of targeted goals, expected outcomes, and accountability. The report on research by the Office of Science and Technology Policy, *Science in the National Interest*,[2] strongly emphasizes fundamental research as it relates to national competitiveness (18). In turn, this relates directly to the agricultural research enterprise. The companion report by OSTP, *Technology for a Sustainable Future*,[3] bears directly on the purposes for agricultural research (19). In the past few months, the Under

[1] The term "agriculture/food/environment" sector is used throughout this report. It is an umbrella term that refers to the entire agricultural production system—including inputs, production and activities at the farm and processing levels, and outputs; the associated food production, processing, and distribution system; and the environmental aspects of both.

[2] See especially the emphasis on basic research, the value of basic research for understanding plant disease infection, and the importance of research for a safe and nutritious food supply.

[3] See especially the compatibility between science for environmental remediation strategies and agricultural and environmental research areas.

Secretary for Research, Education, and Economics has presented five emphases for USDA's research and education program that align quite closely with the six purposes for research and the seven criteria for sustainable agriculture established by Congress in FACTA.

IMPLEMENTATION OF THE PURPOSES

The Secretary has not established guidelines for USDA overall, and individual research units have not established them for their programs. However, some actions have been taken with regard to individual agencies.

Agricultural Research Service (ARS)

ARS, with about 36 percent ($679.2 million) of the total federal agricultural research and extension appropriation for FY 1994 ($1,885.7 million), is a major part of the federal research portfolio[4] (30). ARS incorporated the FACTA purposes into its six-year implementation plan. The plan also sets forth ARS policies that ensure a focus on the purposes, including operating practices, setting of research priorities, and reward systems. ARS believed it had adequately met the Congressional expectations for the agency to establish guidelines to implement the purposes. However, some in Congress and others outside USDA did not consider the ARS action sufficient. A significant impediment to establishing these guidelines was a lack of clarity concerning what was meant by "guidelines." ARS is now addressing this issue by realigning its program planning, priority-setting, budgeting, project selection, resource allocation, accountability, and reporting systems with GPRA and customer service requirements. Also, ARS is adopting the FACTA purposes as its strategic planning goals and as the basis for stating expected outcomes and performance measures. This process also embodies the five priority research areas established by the Under Secretary for Research, Education, and Economics. The new ARS strategic plan is expected to be completed in 1996 (15).

Program guidance within ARS means setting performance goals that are measurable and quantifiable, and to use a meaningful and measurable method for pursuing the intent of the purposes without stifling creativity and productivity. ARS is also determining how to prepare an integrated approach for addressing the purposes, the five priorities of the Under Secretary, and the requirements of the GPRA. In addition, there is some potentially very useful work under way to integrate ARS and state agricultural experiment stations (SAES) planning and operations more effectively. This work is discussed further in the following section.

Cooperative State Research, Education, and Extension Service (CSREES)

CSREES is the direct successor to the former Cooperative State Research Service. Its principal responsibility is managing and overseeing the federal/state partnership for agricultural research, education, and extension in close collaboration with the SAES, the state cooperative extension services, and the land-grant colleges of agriculture. This partnership was first established through the Morrill Act of 1862, and then effectuated more specifically through the Hatch Act of 1887 (for agricultural research), the Second Morrill Act of 1890 (which aimed to involve the historically black colleges and universities in agricultural research and education), the Smith-Lever Act of 1914 (for extension), and subsequent acts. Because of these extensive research responsibilities and relationships outside USDA, CSREES is the department's principal extramural research agency. In addition, CSREES is responsible for the National Research Initiative Competitive Grants Program (NRICGP), which is USDA's principal extramural, competitive grants agency (see Chapter 3).

CSREES receives about 17 percent ($325.2 million in the formula and special grants catego-

[4] These and other data in this section are based on requested data of USDA as well as published data.

ries) of the federal research portfolio; it receives another $103 million for competitive grants. The state land-grant and related institutions that receive these funds play a very large role in the national agricultural research and education portfolio, when all funds are considered: they receive more than $2 billion from a variety of federal, state, and private sources. Of that figure, $648.5 million is from federal funds (for FY 1993), and of these federal funds, $399.0 million comes from USDA. The remainder comes from other federal grant programs, including those run by the National Institutes of Health and the National Science Foundation. Given the small proportion of funding from USDA for state and land-grant partner research and extension, the department plays a significant support, but not necessarily an agenda-determining, role (17).

CSREES has not promulgated guidelines to implement the FACTA purposes. Nor has it done an analysis to determine how relevant the purposes are to the federally funded research projects for which it is responsible. However, because of the long-standing partnership between USDA and the states, and because of USDA's fiduciary responsibilities for these federal funds, which are allocated to the states, CSREES has long taken a strong, active role in planning and managing the funds and in assisting the planning and management of programs funded by them.

This is reflected in actions CSREES has taken, and is initiating, that relate directly and indirectly to the purposes and guidelines of the research title. First, instructions have been sent to the directors of the SAES and State Cooperative Extension programs requesting that their federally funded programs be consistent with the purposes. Second, the purposes have become central to several aspects of research planning and collaboration. For example, a strategic agenda for CSREES-related extramural research programs is being prepared consistent with the purposes. Third, the SAES Strategic Planning Committee is interested in using the same general areas of the ARS six-year plan for its own strategic planning. If this takes place, the relationship between SAES and ARS planning has the virtue of establishing planning and programmatic relationships between two central elements of USDA's research system—which in turn provides a significant opportunity for programmatic integration and collaboration that has heretofore not been possible. Fourth, the four regional associations of SAES directors are in process of setting priorities for regional research programs. Fifth, to bridge gaps between program and purposes, an effort is under way to bring together strategic planning for the state system and CSREES, to provide a common response to the GPRA. And sixth, attention is being given to linking outcomes, and performance indicators for them, to the purposes.

If this system can be established and operated, ARS, the SAES, and the extension systems could jointly establish major outcomes (to meet the FACTA purposes and address key national issues) and identify the performance indicators (and hence the programmatic work) necessary to achieve the outcomes. Such a move would augur well for a more integrated system and focus attention on outcomes and performance. Present plans are to focus on a set of major issues of national concern.

National Research Initiative Competitive Grants Program (NRICGP)

The NRICGP accounts for about 6 percent ($103 million) of total federal funding for agricultural research. The NRICGP staff have included the FACTA purposes in their program announcements. The instructions to applicants for NRICGP grants, and to reviewers, make it clear that all research funded by the NRICGP must be relevant to the long-term sustainability of agriculture. Further, the NRICGP has evaluated its research grants to determine the extent to which they meet the purposes established by Congress. All of the research is believed to apply directly to those purposes. Chapter 3 on the NRICGP provides additional information and perspective.

Economic Research Service (ERS)

The research of ERS totals 2.9 percent ($55.2 million) of the federal funding for agricultural research. Virtually all of it is allocated for intramural studies. No evident actions have been taken to directly address the Congressional purposes.

Forest Service (FS)

The FS research budget comprises about 10 percent ($193.1 million) of the total agricultural research budget. Virtually all of this is spent intramurally. No evident actions have been taken to directly address the Congressional purposes.

Clearly, guidelines to implement the Congressional purposes have been established in a haphazard fashion. More certainly could have been done. However, the real issue is to what extent the purposes have been met. Given the constraints of this study's design and duration, it has not been possible to make an analytical determination of the extent to which the purposes have been met, or to what extent the emphases for federally funded agricultural research have changed. Some changes have obviously occurred. One good example is the increased emphasis on sustainable agriculture throughout USDA's programs and activities. Specifically, all competitive research grants administered through the National Research Initiative Competitive Grants Program (also authorized in FACTA) must be relevant to the long-term sustainability of U.S. agriculture, in addition to being of high scientific merit.

Rather than focusing on the reasons why guidelines were not established, the next section addresses the key issues of relevance and accountability in terms of the characteristics and context of the research enterprise, and in terms of how Congress' intentions might be put into action.

RELEVANCE AND ACCOUNTABILITY: KEY CHALLENGES AND PERSPECTIVES

In the purposes for the research title of FACTA, Congress clearly gave high priority to relevance and accountability for the federal agricultural research and extension system. Implicitly, Congress expressed its dissatisfaction with the lack of attention given by the system, at least prior to 1990, to major issues affecting the nation's agricultural and food system, including the vitality and quality of rural communities and economic life.

The way Congress chose to focus on relevance and accountability was by setting out six purposes for the federally funded agricultural research and extension programs and by asking that USDA guidelines be promulgated to ensure that the purposes would be implemented. Both purposes and guidelines are essential first steps. But a number of questions arise: Are purposes and guidelines sufficient? Are they optimal approaches? Why has there been only limited implementation to date, and what are we to make of it? And how can the future be considered?

Altering the direction and management of research and application—in this case, to achieve certain purposes and ensure accountability—is a challenge under any circumstances. In meeting this challenge, a number of contextual factors and characteristics intrinsic to any research enterprise must be considered and dealt with. Some of these include (i) duration and momentum of research; (ii) the importance of purposes and guidelines, and their limitations; (iii) context and characteristics of the agricultural research system itself; (iv) the dichotomy of top-down versus internal direction.

Duration and Momentum of Research

Research has a long-term flow, and it cannot be abruptly stopped and started without sacrificing results and progress. Scientists and their managers are understandably loath to waste resources and time in a start-stop, start-change way, particularly given the long investment and start-up times usually demanded by good research. Thus, there is a built-in lag in conversion from one research direction to another, and significant transition times are often required.

Purposes and Guidelines: Importance and Limitations

Specifying purposes for a research enterprise is important. Guidelines for efficacious management to achieve the purposes are appropriate. Good management requires both. However, no matter what their specific intentions and how well intended, purposes and guidelines must inevitably be written broadly. Such broad directives ensure that opportunities to explore the full dimensions of a topic are not lost, and provide for individual creativity and innovation. With regard to agricultural research, purposes and guidelines could address a range of issues: much of traditional agricultural production, productivity, and cultural practices research fits with sustainable agriculture, and much of the entomology, plant pathology, and pest management research fits with biological control of pests. It would not be difficult for individual investigators and managers to believe, accurately to them, that their current work and future directions fit well within such purposes and guidelines. However, others outside the research system may not believe that such broad interpretations adhere sufficiently to stated purposes. There is the very real possibility of unproductive confusion and even contention.

Context and Characteristics of the Current Agricultural Research System

For the agricultural research system—broadly defined—there are a number of key contextual factors that bear directly on the efficacy of purposes and guidelines.

First, the system is highly decentralized and multifaceted, incorporating a number of major research agencies. This decentralization, both inside and outside USDA, is an impressive feature of the system. It also makes adhering to centrally established purposes and guidelines difficult at best. Further, the land-grant research partners are major participants in the federal agricultural research system. They receive their funding from state, private, and other sources, in addition to federal funds (which are usually only a small fraction of their research budgets). These diverse funding sources from outside the federal government add to the complexity of this decentralized system.

Second, appropriations for USDA ($1,885.7 million) are less than one-half of the overall funding of the agricultural research system. It is not obvious that the small fraction of federal funds in the state and land-grant partners research programs can have a predominating influence on those programs, both because of the amounts and also because of the longstanding discretion accorded state and land-grant research and extension program managers.

Third, the agricultural research and extension system is to a large degree user-based. Both traditional and more recent user and stakeholder groups have a deep, longstanding claim on the system. Any efforts to transform so that it adheres more closely to purposes and guidelines must also take into account the need to transform user and stakeholder expectations.

Fourth, there is an unusually broad array of functions intrinsic to and embedded in the federal agricultural research and extension system. These functions range from the most basic research (such as genome studies, mathematical biology, and secondary products of plant metabolism) to the most applied and developmental studies (such as testing and applying of new design and manufacturing principles for devices, machines, and products). Furthermore, the applications function is embedded strongly in the cooperative extension system, which itself is closely attached to, and often inseparable from, the research function. This "ingrained intimacy" of function is one of the exceptionally strong attributes of the agricultural research system. It also tends to thwart efforts to adhere to purposes and guidelines and other management directions.

Fifth, just as the functions extend across a broad range, so do the disciplines involved in the agricultural research system. They range from fundamental molecular and cellular biology, mathematics, chemistry, and physics to ecology, environmental biology, and soil and geosciences to the classically agricultural disciplines for the

plant and animal sciences, including the pest protection-oriented disciplines. Meshing all of these disciplines to align with purposes and guidelines is difficult, at best, absent a guiding construct that involves them meaningfully in specific directions.

Sixth, the planning system for the agricultural research system is a combination of planning for the intramural research agencies (such as ARS, ERS, and FS), the extramural competitive grants program (the NRICGP), and the extramural agencies (such as the state agencies and land-grant partners). Program planning for the first two has traditionally been more directed as to areas, program focuses, and resource allocation than the last (the state and land-grant partners). This befits the relative autonomies of the three parts. However, even the planning for the state and land-grant partners is more planning for emphases for funds acquisition (which is centralized through USDA's budget) rather than for fund allocation (which is decentralized at the state and land-grant levels). This basic dichotomy does not encourage program planning consistent with federal purposes.

The Dichotomy of Top-Down Versus Internal Direction

A serious organizational challenge is whether efficacy in research best comes from top-down direction or from internal direction. Top-down direction of a research program, such as established by purposes and guidelines, is necessary but not sufficient. Although it may be satisfying to managers, top-down direction is less than optimally effective with scientists who are primarily self-motivated. Alternatively, internal direction can run the risk of flowing slowly over time to projects that, while interesting, may be neither important nor contribute to overall purposes and goals. A creative combination of the two approaches is most appropriate.

Given this array of context and characteristic for the research enterprise, the challenge then becomes how best to encourage and reinforce the direction of research and application consistent with the purposes of FACTA. The key issue is philosophical, and it strikes to the very heart of the successful research enterprise:

> To what extent should a central research management agency, the Department [USDA] in this case, specify or write guidelines as to how and on what major research and extension is to be done ("top down" direction) as contrasted with the extent to which scientists and appliers/extenders should be provided incentives and encouragement so they can choose their own directions within established policy parameters ("bottom up" direction)?

The aim must be to set up a system of clear directions—coupled with strong, attractive *incentives and benefits* for the participants—that *empower persons* to work toward established goals. One caveat must be that research programs need to be based on and suffused with fundamental research providing foundational knowledge, and with the opportunity and encouragement to stimulate creativity and innovation, no matter where they may lead.

APPROACHES TO ACCOMPLISHING PURPOSES

Different approaches can be considered for meeting the purposes established by Congress. One approach is for the research and extension enterprise to continue as it has been. Given the strength of Congress' conviction that change is desired, the status quo would not seem to meet Congress' agenda.

A second approach is to adjust and modify the current programs in the belief that continuous improvement, always laudable, is sufficient. Given the intentions and interests of Congress, this also seems insufficient.

A third approach, intended by Congress, is to establish guidelines to encourage and guide pursuit of the purposes. Such guidelines could and should include a number of useful and valuable mechanisms, such as creating program plans and convening program performance reviews that address the elements of the research enterprise overall and also the key dimensions established

in the purposes; using review and approval systems for new projects that would encourage or require adhering to the purposes; and making hiring and resource allocations based on the purposes. Even though such guidelines involve top-down direction, they are also good management practices. However, if there is not a clear structure of priority and direction within which these guidelines are implemented, then much of this emphasis will be for naught. More than guidelines is needed.

A fourth approach is to establish a clear set of operational program goals and objectives within a strategic context. Operational goals and objectives are necessary to guide specific decisions. A strategic context is necessary to ensure adequate long-term direction and to identify and secure the roles and opportunities for participation from all participants in the agricultural research and extension enterprise. This approach also has top-down characteristics, but it has the distinctive value of establishing priorities, and providing financial incentives that reflect a broad, societal view. It has the disadvantage of being forced on an organization with its own pre-existing momentum and culture, and with slow and long response times.

For this approach to be optimally effective, it is essential that goals and objectives within a strategic context be established through direct involvement, and ultimate concurrence, of major programmatic leadership from the scientist-applier/extender community. Scientists and appliers/extenders should be directly involved in developing the plans and guidelines to be used. They will then have the maximum opportunity to understand, be acclimated to, and provide their own perspectives on how to achieve the most efficacious response.

This approach makes a key contribution by providing a comprehensive basis for making allocation decisions that support the purposes and provide incentives for participation in the necessary research. If resources are not applied to priorities, the exercise is hollow. Guidance language for this decision process can be general and provide for internally directed responses. Alternatively, it can be more tightly drawn and focus more attention on key issues and topics. Each approach provides for internalized incentives—that is, scientists can make their own decisions about participation. Focusing attention and commitment has the advantage of effecting more rapid change.

Unfortunately, given the highly decentralized and variegated nature of the agricultural system, it is unlikely that such a broad, comprehensive approach can be fully effective, at least in addressing key contemporary issues of the kind Congress has emphasized. Something more is needed.

A fifth approach addresses both the operational and strategic planning requirements outlined above, while emphasizing key contemporary issues. This approach can create "unified strategic research and applications/extension plans" for key contemporary issues of major national interest. The plans would be both strategic (focusing on what direction, how different parts of the system participate, with what expectations) and operational (focusing on how resources are deployed and for what purposes). This approach combines breadth of scope and thinking—of inclusiveness of the entire research system—with the specificity of focusing on pressing national issues.

Strategic plans focused on key contemporary issues (for instance, one plan per issue) would outline (and specify to the extent possible) the applications and associated information and knowledge needs useful for addressing the issues, identify the sources and means for securing those needs and resulting applications, and propose the best form for applying the knowledge to address the issues. All elements of the agricultural research portfolio, and the extension and application agencies as well, would have identifiable roles and responsibilities in these plans. To the fullest extent practicable, the agencies would be integrated and coordinated with one another to achieve optimal leverage of resources and cost-effectiveness. This approach is further addressed in the chapter on the

National Research Initiative Competitive Grants Program.

An obvious advantage of this approach is that respective roles and responsibilities for national issues would be clear. Possible shortcomings of this approach are that it smacks too much of central planning and direction, and predicts in advance what should be done to achieve success. The latter is useful when technologies and methods are ready to be applied or can readily be developed. It is rarely useful—and is, indeed, usually counterproductive—in the research enterprise. The former can be done with prudent, careful, nonobtrusive coordination combined with some financial resources.

These last two approaches go beyond stating purposes and establishing guidelines. They address the central issue: guidance for allocating funds. If funds are not allocated to priorities, it is not entirely possible to plan and posit direction.

A sixth approach is to expand significantly the concept and practice of competitive grants programs to address the major issues of interest. Competitive grants focus attention by rewarding high-quality ideas with funding that attracts strong, active researchers. Indeed, the record from the biomedical research arena shows that such grants have garnered unusually strong and long-term attention from top scientists. A major virtue of competitive grants is that they are probably the most effective mechanism for securing rapid response and alignment of direction and purpose with scientist interest *and* they do it in a manner consistent with the principles that animate the best scientists—pursuing their own intellectual directions in their own way. A problem with competitive grants is that they are not long enough for scientists to complete a full body of work to address a problem. They also do not usually provide for the long-term work on biological systems that is often required for agricultural, environmental, and ecological topics. In spite of the oft-voiced frustration of scientists that "grantsmanship" and the repeated preparation of proposals takes too much time, the careful refinement of ideas within a competitive environment should improve research direction and conception. Notwithstanding some obvious deficiencies with competitive grants, they are an attractive approach for addressing major contemporary issues.

A seventh approach is to incorporate an accountability mechanism into guidelines, so that management and outcomes can be evaluated in a regular, ongoing, systematic manner. The guidelines would outline and/or describe how accountability and relevance are to be measured and evaluated. The emphasis would be on after-the-fact evaluations, most usefully in connection with future allocations of funds and other resources. They would complement evaluations made at the outset of research.

Each of these approaches have their advantages. Combining them preserves the advantages and obviates the disadvantages. Thus, as a prospectus for the future, each of these approaches should be used and combined appropriately into an overall program.

National Research Initiative Competitive Grants Program 3

Congress in FACTA authorized the National Competitive Research Initiative (known generally as NRI, but in USDA as the National Research Initiative Competitive Grants Program, or NRICGP). This pivotal action affirmed Congress' commitment to funding research for foundational knowledge through competitively awarded grants that would be initiated by researchers and reviewed by their peers. Such a commitment to competitive grants for USDA was first made in 1978, when Congress authorized USDA's Competitive Research Grants Office (CRGO), and appropriated $15 million to start the program. The basis for the CRGO was due, in large part, to findings from the 1977 OTA report *Organizing and Financing Basic Research to Increase Food Production* that pointed out the need for a significant focus on basic research for agriculture (28).

Through FACTA, Congress expanded the competitive grants program and specified six high-priority research areas for NRICGP: plant systems; animal systems; nutrition, food quality, and health; natural resources and environment; engineering, products, and processes; and markets, trade, and policy. These six areas encompass virtually all topics relevant to the knowledge and research needs of the agriculture/food/environment sector. To implement NRICGP, funding was provided for the first four areas in FY 1991 and for the last two areas in FY 1992. Consequently, there is now funding for competitive grants across the entire agriculture/food/environment spectrum. Congress also strengthened the peer-review and advisory oversight of the program; authorized funding for multidisciplinary research; authorized research on long-term mission-linked research problems and provided for developing the research capacities of institutions and individuals. The basis and the specific provisions for this program were derived to a large extent from the 1989 report of the Board on Agriculture/National Research Council (BA/NRC), *Investing in Research* (5).

The purpose of NRICGP is to provide the basic knowledge necessary to discover new principles and to serve as the basis for applied- and problem-oriented studies, just as fundamental research sponsored by National Institutes of Health (NIH) provides new principles and serves as the basis for applied studies and clinical work in the biomedical and health sector. Such "foundational knowledge" addresses the basic characteristics and interactions among biological, physical, and social phenomena—which, by their

nature, are generic and broadly relevant as the foundation for more applied studies.

Both the BA/NRC report and the Congressional language of FACTA also speak to "mission-linked research." This research is composed of those studies—basic and applied—designed and carried out to make early connections to applied topics. This research was included in the original BA/NRC report to provide a place for studies that are more closely connected to mission applications, generically national in impact, and also have characteristics of fundamental studies providing foundational knowledge. They were included to strengthen the continuum from foundational knowledge to more applied studies. As another means for connecting the foundational research to application, the BA/NRC report specifically speaks to applications experts, including Cooperative Extension specialists, being involved in this mission-related research and in the related multidisciplinary research to allow for easier technology development, transfer, and application.

Like other federal extramural basic research programs, NRICGP specializes in proposals that are initiated by investigators and evaluated by peer review (also termed merit review) to assess their scientific quality and relevance to high-priority areas in the agriculture/food/environment sector. Only proposals that are relevant to the sector are funded through competitively awarded grants based on merit.

Congress specified in FACTA that NRICGP must allocate its funds so that mission-linked research is at least 20 percent of NRICGP (which means that fundamental research may comprise up to 80 percent of the research); multidisciplinary research is at least 30 percent of the program by 1993; and research and education strengthening is at least 10 percent. These requirements are extraordinarily strong, and appropriate, for multidisciplinary research because of the multifaceted scientific dimensions of key research questions relevant to the agriculture/food/environment sector. The requirements further strengthen the intention of Congress that fundamental research is to be relevant to the major issues in the sector. The fact that up to 80 percent may be fundamental research emphasizes the urgent need for a wide range of foundational knowledge. In fact, if foundational knowledge were to be deemphasized, much of the value of NRICGP would be diminished or even lost.[1]

NRICGP IN RELATION TO USDA'S RESEARCH PORTFOLIO AND THE FEDERAL EXTRAMURAL RESEARCH SYSTEM

NRICGP contributes significantly to and fits well with USDA's overall research portfolio as well as with the federal extramural research system. ("Research portfolio" means the several agencies and funding mechanisms within USDA that are responsible for research and their research programs.) The portfolio contains the *intramural* research programs of the Agricultural Research Service (ARS), Economic Research Service (ERS), and the Forest Service (FS). The portfolio also contains several *extramural* programs. A major component of these extramural programs is the partnership between USDA and the State Agricultural Experiment Stations (SAES), as well as the 1890 colleges, for conducting state- and college-initiated agricultural research. This research is funded by so-called formula funds—Hatch, Regional Research, Evans-Allen—that are allocated to SAES and the 1890 colleges. Another component of the portfolio is the program of special grants to support national and regional (and sometimes more local

[1] There is, of course, always a need for more mission-oriented research. However, there are a number of mechanisms and funding sources for mission-oriented research, including ARS, both federal and state elements of the SAES system, and private sector sources. NRICGP is the only mechanism and funding source that aims for foundational knowledge. It is reasonable to emphasize this focus, rather than sacrificing it to other focuses that are already emphasized by all other parts of the agricultural research enterprise. This contention is discussed further in the next section and in a later section.

and site-specific) research topics. In general these funds, too, go to SAES and 1890 colleges. Cooperative agreements and contracts are also available, usually between SAES and 1890 colleges with units of USDA.

NRICGP holds a distinctive place in USDA's overall research portfolio as a consequence of its emphasis on foundational knowledge and its openness to all qualified scientists. Other elements of the portfolio emphasize intramural research (ARS, ERS, and FS) and a combination of fundamental and applied research conducted largely in an intramural manner (the SAES system). NRICGP's role with regard to the agriculture/food/environment sector may, in fact, be compared with the role that NIH's extramural research program plays in relation to the biomedical and health sector. NRICGP may also be compared with the National Science Foundation (NSF) as a place for the nation's scientists involved in the biogeochemical, biological, environmental, and engineering sciences.

NRICGP fits well with USDA's programmatic issues. Its research applies throughout USDA's overall program, by virtue of the comprehensive coverage of the agriculture/food/environment sector afforded by the six priority research areas. It also fits well with contemporaneous issues such as sustainable agriculture and agricultural systems, water quality, global climate change, and genome studies, as evidenced by the incorporation of these research needs into its portfolio.

NRICGP provides distinctive advantages to USDA's overall research program. First, the competitive grants program of NRICGP is the major, often the only, means for federal funding of *any* qualified scientist—irrespective of institutional or disciplinary affiliation or local academic or research unit—to work on topics of direct interest to the agriculture/food/environment sector. This makes it possible for all qualified scientists with relevant research ideas to compete for funds and, if the funds are awarded, to participate in USDA's—and the nation's—research mission for agriculture, food and the environment. Second, because competitive grants are for limited periods of time, they provide a strong, responsive mechanism for addressing priority topics and they provide major flexibility in focusing on national needs and priorities. Third, NRICGP provides a distinctive mechanism for research to complement formula- and state-funded state research and the long-term intramural research of USDA's agencies. NRICGP thus serves diverse national needs, along with USDA needs.

Funding for NRICGP has increased from \$46 million in 1985 (3.5 percent of the total USDA appropriations for research and education of \$1318.7 million) to \$103.1 million in 1995 (5.4 percent of the total appropriations of \$1,900.7 million). Irrespective of the rate of increase of funding for NRICGP in 10 years, the funding level is still only a small fraction (about 6 percent) of the total USDA research and education (and extension) budget.

Just as NRICGP provides a distinctive component in USDA's research portfolio, it also provides a distinctive contribution to the federal system for extramural research. The federal extramural research system has a number of components, depending on the agencies involved. It operates through several different, usually complementary mechanisms including: (i) investigator-initiated, competitively awarded, peer-reviewed grants; (ii) cooperative agreements; (iii) contracts; and (iv) major institutional relationships such as between universities and the Department of Defense (DOD), Department of Energy (DOE), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) laboratories and, of course, USDA. Among these agencies, competitively awarded grants to support investigator-initiated research are an especially important component of the federal extramural research system. This is the predominant mechanism used by NSF, to a large degree (about 80 percent) by NIH, and significantly by other agencies such as the Environmental Protection Agency (EPA) and DOE. They provide the most open access to research opportunities for scientists throughout the country,

regardless of institutional or disciplinary affiliation.

A key effect of Congress' reaffirmation of competitive grants for agriculture and expansion of CRGO to form NRICGP was to make it a more integral and significant participant in the overall federal extramural, competitive grants system long characterized and dominated by NSF and NIH. Valuably, Congressional actions make NRICGP—and USDA's mission—much more attractive to scientists outside the traditional agriculture research sector, just as the NIH program is attractive to scientists outside the biomedical sector. It thus provides for the widest participation of qualified scientists, irrespective of whether they come from the SAES system or from laboratories not at all associated with colleges of agriculture. All of this is appropriate and should, in the long run, provide the best science to help ensure the competitiveness and sustainability of the U.S. agriculture and food system.

IMPLEMENTATION

A number of key steps to implement NRICGP have been taken. These include (i) reflecting the FACTA purposes in the program's description; (ii) establishing key advisory mechanisms, including potential positive relationships between foundational knowledge and technology transfer; (iii) consulting broadly and regularly with user groups and stakeholders; (iv) collaborating with related federal agencies and research leaders; (v) taking steps to make the program more attractive to investigators by increasing the amount and duration of grant awards (for details, see a later section); and (vi) managing the program effectively and efficiently.

Purposes

The purposes specified by Congress for USDA's research are prominent in the program description for NRICGP, which "requires that research supported by NRICGP address, among other things, one or more of the...purposes." The guidelines to implement the purposes—sought by Congress through the conference report for FACTA—are considered to be the specific program descriptions, priorities, and research areas presented in the annual program description.

Advisory Mechanisms

A three-part advisory system has been established for NRICGP. For its part, USDA has established NRICGP's board of directors. It is chaired by the Under Secretary for Research, Education, and Economics and composed of the administrators of ARS, CSREES, and ERS, the Deputy Chief for Research of the FS, the director of the National Agricultural Library, and the chief scientist of NRICGP. The board establishes internal operating policy for NRICGP, including approval of the annual program description and request for proposals. The board has the added advantage of integrating USDA's research agencies—especially ARS, ERS, FS, and the CSREES—more closely with the program.

The National Research Initiative Competitive Grants Scientific Advisory Committee is authorized through a USDA regulation. A similar committee was established for the predecessor Competitive Grants Program, starting in 1978. The purpose of the committee is to provide recommendations on the scope and focus of the programs carried out by NRICGP to meet the goals and mandates of Congress. The committee may also advise the Secretary on NRICGP regarding matters such as programs, policies, priorities, operating procedures, and desirable corrective actions needed. The committee is to comprise twelve scientists broadly representative of the disciplines and research areas of NRICGP, and its membership is selected by the administrator of CSREES and approved by the Secretary of Agriculture (through the Under Secretary for Research, Education, and Economics) and by the White House.

The regulation provides for the committee within the limits authorized for USDA, and it requires the committee to be reauthorized by USDA every two years. The committee first met in August 1992. However, it was not reautho-

rized in January 1993 after its first two-year term. After a hiatus, the committee was reauthorized in 1994. The chief scientist has now identified candidates for the 12 positions, including two alternates, and made recommendations for the committee. Although the reactivation and forthcoming appointments are commendable, this kind of hiatus is unacceptable. There is no obvious substantive reason why the committee is subject to recurrent two-year authorization by USDA. A distinctly preferable system would be to have the committee authorized indefinitely, with provision for its termination for cause. Further, its members should be appointed on a "rolling basis," with staggered three-year terms to provide for overlap of membership and consequent continuity.

The third advisory relationship was established by Congress through FACTA, consistent with its interest in technology development and transfer. Congress provided that the Secretary "may consult with the Agricultural Science and Technology Review Board, established by Section 1605 of the Title, regarding policies, priorities, and operations" of NRICGP from the perspective of technology evaluation and transfer. This consultation has not been done to date, in part because this board, formed in September 1992, has focused on its own mandated responsibilities (2, 24).

As the relationship between foundational knowledge and technology assessment function is contemplated, caution is urged in expecting too many direct relationships between results from research funded through NRICGP and technology transfer more generally. Technology transfer[2] is an intrinsically difficult matter. In relatively rare instances, the technologies derive directly from fundamental research. Generally, technology transfer occurs most readily and often from the more applied, developmental research that characterizes other parts of the USDA's portfolio. The purpose of NRICGP is to furnish the foundational knowledge that makes possible this applied and developmental research. Nonetheless, the relationship between the board and NRICGP should be made as expeditiously as possible.

Stakeholder Relationships

In organizing NRICGP, USDA has been consulting with outside groups, including commodity organizations, senior representatives of scientific societies, and advocates of sustainable agriculture. For example, USDA convened Users Workshops in FY 1991 covering seven different subject areas and in FY 1993 covering nine subject areas. In the process, there were consultations with more than 200 industry, scientific, and related user groups and stakeholders. In addition, USDA focused specifically on concerns that sustainable agriculture, and particularly its social dimensions, were not adequately represented in NRICGP's first program solicitations (7). These concerns were relevant because (a) funds were limited in the start-up appropriation for FY 1991; and (b) the social science and rural development components, both important for sustainable agriculture, were not funded by Congress until FY 1992. Item (b) has been addressed. Currently, there is significant funding awarded for grants that are directly applicable to these areas (such as $14.7 million in FY 1994 for sustainable agriculture), in addition to much of NRICGP portfolio which is also relevant to them. Also, the program staff gave specific attention to stakeholders in sustainable agriculture, meeting regularly with them and including at least one representative in each workshop.

There is obviously value in sustaining the ongoing connection between NRICGP major user and stakeholder groups through these workshops and the scientific community through the Scientific Advisory Committee. Both should be firmly established as features of the program and kept in continuous use.

[2] For a discussion of agricultural research and technology transfer policies, see *Agricultural Research and Technology Transfer Policies for the 1990s*, Office of Technology Assessment, U.S. Congress, 1990.

Collaboration with federal agencies. A key, productive part of implementation of NRICGP has been its collaboration with related federal agencies. Because of its purpose and method for providing rigorous peer review, NRICGP is a major participant, along with other agencies, in several significant interagency programs and has established positive rapport and regard among related federal extramural granting agencies. These interagency programs include the Plant Biology Program; the Global Change Program; and *ad hoc* discussion groups of mutual, multi-agency interest such as plant molecular biology and microbial physiology. For example, USDA together with DOE and NSF established by cooperative agreement in 1992 the Joint Program on Collaborative Research in Plant Biology. NRICGP, along with DOE and NSF, provides the merit review of research proposals for the program.

This collaborative approach continues. For example, in FY 1995, a new program on Terrestrial Ecosystems (TECO) was established jointly among NRICGP, DOE, NASA, and NSF. In the collaborative Global Change research program, USDA has the lead responsibility for establishing the UV-B monitoring network. NRICGP is specifically responsible for funding development of the sensitive instrumentation required. There have been recent discussions among NRICGP, DOE, and NSF about mapping the entire genome of *Arabidopsis*, a plant widely used in fundamental plant biology research.

There are also several collaborative programs between NRICGP and USDA agencies. For example, for USDA studies on the plant genome, ARS and NRICGP collaborate, with NRICGP being the lead agency for merit review of proposals. USDA has a memorandum of understanding with EPA and the Food and Drug Administration (FDA) regarding integrated pest management (IPM), and NRICGP's responsibility is providing relevant foundational knowledge. Further, NRICGP programs relevant to IPM are closely coordinated with other IPM programs in USDA (22). Regarding water quality, there is a joint program between NRICGP and the special grants water quality program in CSREES, with each partner providing one-half the funding. The program is administered by a single scientist.

In all of these examples, NRICGP's chief scientist and program directors and their counterparts in other agencies—such as NSF, NIH, EPA, and DOE—have collaborated to discuss areas of mutual interest, determined how to create a unified program among the agencies consistent with the separate agency missions, and determined the best strategies for collectively funding qualified proposals. The directors of these agencies also jointly consider the effectiveness of the administration of their peer review procedures. These collaborations provide for greater effectiveness within the overall federal effort in these research areas of interest to two or more agencies, and the partnerships that result provide substantial leverage of funds and interests of the agencies.

The value of these collaborative programs is that they provide for larger grants, often required for success in these subject areas; permit significant training components to be done concurrently with the research, thereby providing additional leverage and value of funding; and allow networking to develop work among scientists that would otherwise be forgone (22). These advantages would be difficult or impossible to attain with single-agency approaches. The effectiveness of these collaborative programs is significant, as judged by NRICGP program staff and as shown by the continued development of these programs.

These relationships of NRICGP with related programs of other agencies, and of USDA, are commendable and should be sustained and expanded as opportunities occur.

Ensuring the program's attractiveness and usefulness for research scientists. A crucial aspect of implementing the program is providing sufficient funding for individual awards to ensure the program's attractiveness and utility. CRGO suffered substantially from having too little funding for too many high-quality requests. In an effort to provide at least some funding for a broad spectrum of proposals, the level and dura-

tion of funding for individual grant awards was substantially less than for either NSF or NIH. This disparity between CRGO (and also NRICGP more recently) and cognate programs in NSF and NIH, for often equivalent kinds of research, hindered the attractiveness of the program to scientists. As funding for NRICGP has increased, USDA has endeavored to increase the amount of awards and lengthen their duration, making the program more attractive to the best scientists and providing for more coherent research programs. However, the relative insufficiency of funds makes it difficult to realize this goal in any significant way. (Because of the importance of this issue, it is discussed in more detail in a later section.)

Internal management of the program. The internal management of NRICGP is comparable to that of the highly successful NSF and NIH extramural grants programs, and the program's staff have regularly sought advice from those programs to supplement their own experiences. Panels of scientists with demonstrable stature in their fields evaluate and rank the proposals in terms of scientific quality and relevance to the long-term sustainability of agriculture (broadly defined). The scientists are apprised, as part of their instructions, of the importance of research for sustainable agriculture and the "relevancy criterion" that all research must be relevant to sustainability if it is to be eligible for funding.

The panels provide their advice on quality and relevance to the chief scientist through the program officers, who make the funding decisions based on funds available. The chief scientist gives final approval. All proposals within a program area—irrespective of whether they are single- or multidisciplinary, mission-linked, or research strengthening[3]—are evaluated by a single panel of scientists who themselves represent a range of disciplines. Only the funded proposals are classified into these categories, and then only after all review is done. As necessary, proposals may be shifted from one program to another because of the topic and with the concurrence of the principal investigator. Only the proposals that have both high scientific quality and relevance to the program description and the long-term sustainability of agriculture are funded. The one caveat to this system is that it may at times be difficult to evaluate multidisciplinary proposals if the panel does not contain sufficient expertise in the dimensions of the proposed research, or if the scientists take a too-narrow view of the subject and try to force a single-discipline perspective on an inherently multidisciplinary problem or approach. The NRICGP staff are aware of this issue and work to ensure adequate breadth of review.

Overall, implementation of the program is positive and productive.

Funding

Funding of NRICGP warrants attention from different, but complementary perspectives: (i) appropriations in relation to authorizations; (ii) sufficiency of funds for the established program; (iii) relevance of the funding to program priorities of USDA; (iii) earmarking; and (iv) attitudes within the agricultural research community to funding of NRICGP. The key issue of whether NRICGP is relevant to contemporaneous issues in the agriculture/food/environment sector is specifically addressed in the next section.

Appropriations and authorizations. One of the most significant implementation actions for NRICGP was Congress's action in FACTA to authorize NRICGP at $500 million dollars. This increases seven-fold the authorization of $70 million provided by the 1985 farm bill. In addition, Congress authorized a phasing schedule (FY 1991, $150 million; FY 1992, $275 million; FY 1993, $350 million; FY 1994, $400 million; and FY1995, $500 million).

[3] Research strengthing refers to a portion of the grants allocated to those universities that have not received the same proportions of federal funding as more established institutions.

The appropriations record is substantially less positive. Appropriations for NRICGP programs have indeed more than doubled in the past six years ($43.1, 73, 97.5, 97.5, 103.1, and 103.1 million for FYs 1990–1995, respectively; see table 3-1). This is about 6 percent of the total USDA budget for agricultural research and education. But these increases fall far short of the amounts authorized in FACTA. They are significantly less than is required to meet priority research needs and than is merited by the number of proposals which can appropriately be funded (based on the relatively low proportion of high-quality proposals for which funds are available). For example, NRICGP cannot even fund all of the "high-priority" proposals in several of the program areas and must limit its funding only to those that are "outstanding." This is discussed further in the next section.

Funding of meritorious proposals was made even more difficult during the past two years because of earmarks (see discussion below) and set-asides required by law for Small Business Innovation Research (SBIR, 2 percent) and biotechnology risk assessment (1 percent of biotechnology-related research). Administrative costs are set by law at 4 percent in 1995. Thus, of the approximately $103 million available in recent years, only about $91–$96 million has been available for actual grants to investigators.

Furthermore, growth of the program has stalled at about $100 million for four consecutive years (FY 1992–95). As a result, NRICGP appears to be languishing at this level and is in serious danger of failing to meet both the need for its research and also the promise for its program.

This funding situation raises the obvious issue of where, and how, to secure additional funds for NRICGP, particularly in the stringent budget climate of 1995–96. One approach is to recognize that additional funding for NRICGP results in a zero-sum scenario wherein funds from other parts of the agricultural research portfolio are redirected into NRICGP. This proved deleterious to all parties in the late 1970s, and it is not a feasible alternative because the other programs provide critical support for research in other dimensions of agricultural research.

Another approach was outlined in 1989 with the initial formulation of the program in *Investing in Research* and mentioned again in the 1994 BA/NRC review of NRICGP (6). According to this rationale, much new foundational knowledge is necessary to serve as the basis for sustaining productivity along with increasing availability of environmentally sustainable cost-effective technologies for all producers, large and small. Without this knowledge, American agriculture will languish. On this basis, then, the source of additional funds for NRICGP could reasonably come from either (or both) of two sources. One source would be inside the current agricultural research system. This means other programs will have decreased funds, as mentioned above, with ensuing problems. Alternatively, the budget mark can be increased, with the increase to be funded from other funds within the federal budget. For example, a policy could be established to use some of the downsizing of the agricultural commodity support programs for funding a portion of this foundational research. The rationale for this action is that the results will lay the basis for subsequent productivity or profitability increases to offset the economic losses from the support programs (and also to increase the viability of non-supported programs). The discussion later in this report on patterns and policies for supporting agricultural research, and delineating public and private responsibilities for the research, bear directly on this key policy issue.

Sufficiency of funds for NRICGP. Sufficiency of funds can be addressed by examining at least seven characteristics: need for the program; interest in the program; demand in relation to quality; sufficient funding for individual awards; availability of the program to the widest possible pool of qualified investigators; sufficiency of coverage of the priority research areas; effect of funding on risk-averseness in making awards; and the management challenge of using funds by the program in a cost-effective manner.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996*
ARS	518.4	552.7	578.2	602.3	640.9	681.4	680.2	706.1	707.8	704.3
CSREES	293.7	303.1	310.6	326.6	373.3	414.4	415.0	425.3	414.6	414.1
NRICGP	40.7	42.4	39.7	38.6	73.0	97.5	97.5	103.1	103.1	130.0
AMS	2.5	2.6	2.7	4.2	4.8	4.7	4.9	4.8	4.8	4.8
APHIS	4.9	6.6	11.3	13.0	15.7	16.7	14.7	19.2	19.1	18.9
ERS	44.9	48.3	49.6	51.0	54.4	59.0	58.9	55.2	53.5	54.7
FAS	4.2	1.5	1.3	2.3	2.6	1.5	1.5	1.4	1.4	1.4
FS	126.7	132.5	138.3	150.9	167.6	180.5	182.7	193.1	199.7	203.8
NASS	3.4	3.6	2.9	2.8	3.2	3.6	3.9	3.9	3.6	3.7
RBCD	2.7	2.7	2.7	3.4	2.8	8.0	9.6	11.4	9.9	19.2
TOTAL	1042.1	1096.0	1137.3	1195.1	1338.3	1467.3	1468.9	1523.5	1517.5	1554.9

* Executive Branch request to Congress, ARS–Agricultural Research Service
CSREES–Cooperative State Research, Education, and Extension Service, NRICGP–National Research Initiative Competitive Grants Program
AMS–Agriculture Marketing Service, APHIS- Animal and Plant Health Inspection Service
ERS–Economic Research Service, FAS–Foreign Agriculture Service
FS–Forest Service, FGIS–Federal Grain Inspection Service
NASS–National Agriculture Statistics Service, RBCD–Rural Business and Cooperative Development

SOURCE: U.S. Department of Agriculture Budget Office, 1995.

There is a strong need for NRICGP, because there is clearly a major need for its foundational knowledge. Fundamental understanding is still lacking for the central biological and biogeochemical processes involved in critical elements of agricultural production, food safety and nutrition, and related environmental quality and conservation of natural resources. For example, fundamental molecular and cellular biology, along with genetics and physiology and biochemistry, are crucial to understanding the biological basis for nitrogen fixation, the cellular and molecular biology of pathogenesis, natural mechanisms of disease resistance in plants and animals, and systems ecology and management in emerging areas such as sustainable agriculture. Without this fundamental knowledge the desired advances necessary for environmentally sustainable productivity and for increasing productivity to meet increased food and nutritional needs cannot be met.

The interest of qualified scientists in the program is also evident. For example, each major increase in appropriations to the earlier Competitive Research Grants Office and now to NRICGP has resulted in a corresponding, and quite proportionate, increase in the number of proposals (for instance, for 1978–84, an average of 842 proposals for an average of $16 million appropriation; for 1985–90, an average of 1632 proposals for an average of $42.4 million appropriation; for 1992–94, an average of 3084 proposals for an average $100.1 million appropriation) (14).

The quality of proposals that has accompanied the increasing interest in the program has remained consistently high, as shown by the generally same proportion of all proposals receiving high ranks by panel reviewers (7). Senior staff of NRICGP estimate, based on evaluations by panel reviewers, that another 25 percent of the proposals could be funded without diminishing quality. One area had about 35 percent of the proposals in the outstanding and high-quality categories; because of funding constraints, only 18 percent (about one-half of these highly qualified proposals) could be funded.

Sufficient funding of individual awards is an important, but difficult and problematic, issue for the program. The constancy of quality of proposals for funding and the increasing interest in the

program has not been matched by available funds. To illustrate the problem, the total award amount, total number of grants, the average size of awards in major grant categories (excluding the strengthening, multiagency, and solar UV-B grants, because of their wide variation in award amounts), and their average duration are shown in table 3-2.

Not only have appropriations been substantially less than authorized (as already noted), they have not been sufficient to fund qualified proposals to appropriate levels and durations. For example, the average amount of the total award was $117,295 for FY 1991, with an average duration of 2.22 years ($52,836/year) and $137,256 for FY 1994 ($58,804/year). These awards are little more than the awards for FY 1988 for the previous program ($50,000/year[4]) (5). Even in 1988, the USDA competitive grants awards were only 72 percent of comparable NSF awards (and 32.5 percent of NIH awards, which would be expected to be higher because of the higher animal and related research expenses, on average) (5). In 1995, the NSF average awards for Biological Sciences were for a three year duration and at $83, 000 per year (8). This means NRICGP awards have declined to about 55 percent of comparable NSF awards. Thus, on the critically important issue of funding of individual awards—in terms of amount of award and duration—the program is woefully inadequate, especially in comparison to the closely related comparison programs in NSF and NIH, and little improvement has been made between the earlier Competitive Research Grants program and NRICGP; the reason for this, of course, is the lack of funding and the desire by both Congress and the NRICGP management to cover all subject areas, even with the limited funds available.

It may be questioned why the award amounts and duration are less than they should be. The reason is the strong desire of the NRICGP staff to involve as many scientists as possible in the program, even with the disadvantage of limiting their funding. Until the appropriations are significantly increased (difficult in these budget times) or the amounts and durations of awards increased (undesirable within the current level funding because of the resulting decreased number of awards), the sufficiency of funding for awards will be especially difficult for the program.

Furthermore, and reinforcing the problem of amounts per award, the multidisciplinary awards for the same period average $144,736 and last 2.4 years. This duration is virtually the same as for single-investigator awards. As regards the amount of the awards, if there are three investigators per award, the funding per investigator is slightly less than single-investigator awards. Even if there are only two principal investigators, the funding is only nominally more than single-investigator awards. These terms are a substantial disincentive for multidisciplinary work, which is difficult even when funding is adequate. To encourage multidisciplinary work there could be a premium provided for doing it, not just an equality, which is itself a *dis*incentive because of the difficulties involved. It is increasingly recognized that multidisciplinary work is highly desirable and useful for addressing the multifaceted research questions confronting the agriculture/food/environment sector. This kind of financial disincentive is not consistent with the goal of attracting scientific talent to address them.

These amounts and durations for grant awards raise a fundamental question which should be forthrightly resolved as early as practicable:

> "To what extent should the NRICGP continue with these current award amounts and durations *or*, alternatively, to what extent should the amounts be raised to be, for example, comparable to NSF awards in amount and duration?"

Raising the amounts and durations to NSF levels would make NRICGP directly comparable to NSF and thus provide opportunity (in terms of research program support) for all scientists to

[4] The amount includes indirect costs of 14 percent.

Priority Research Areas	1991 Total $ awarded[a] (000)	1991 Total number of awards	1991 Average award size[b] ($)[c]	1992 Total $ awarded (000)	1992 Total number of awards	1992 Average award size ($)	1993 Total $ awarded (000)	1993 Total number of awards	1993 Average award size ($)	1994 Total $ awarded (000)	1994 Total number of awards	1994 Average award size ($)
Plants	33,180	NA	96,897	37,795	360	110,539	37,608	371	106,952	37,211	378	103,169
Animals	18,960	NA	154,247	23,622	156	167,426	23,519	156	168,983	21,068	149	157,421
Nutrition, Food Quality and Health	3,792	NA	126,400	6,142	51	130,673	6,134	49	133,742	6,766	49	149,171
Natural Resources and Environment	13,272	NA	118,663	17,008	143	137,940	16,994	146	127,277	20,647	169	129,682
Processing for Value-Added Products	NE	NE	NE	3,780	29	139,751	3,777	32	133,583	5,598	44	144,322
Markets, Trade and Development	NE	NE	NE	3,792	38	104,629	3,782	36	110,087	3,410	33	107,545
Agricultural Systems	NE	NE	NE	NE	NE	NE	NE	NE	NE	1,930	11	175,442
Total	69,204		117,295	92,139	777	126,998	91,814	790	124,846	96,630	833	137,256

SOURCE: Annual reports of the U.S. Department of Agriculture, National Research Initiative Competitive Grants Program.

Research areas of the NRICGP in FY 1994; correspond to those in FACTA, Agricultural Systems was added by USDA.

NA, not available,. NE, not established.

[a] Includes all awards, including for strengthening, multi-agency, and solar UV-B

[b] Does not include awards for strengthening, multi-agency, and solar UV-B because of their variation in size. Year, number, and average duration for the included awards: 1991, 592 awards, 2.22 yr; 1992, 675, 2.14; 1993, 704, 2.1; and 1994, 743, 2.35.

[c] Includes indirect (research support) costs of 14% of total award amount.

participate in the fundamental research mission for the agriculture/food/environment sector equivalent. This would have the effect of research for this sector being as attractive for its segment of researchers as NIH is for its segment of researchers. Achieving this would be a distinct advantage for the sector. If this were done, however, within the current appropriation levels, it would also have the effect of reducing by about 25 percent the researchers who would be funded[5] and, inevitably, of reducing the scope of coverage of the program. The tradeoff, then, is larger award amounts and durations (and thus more appeal to more investigators, with an expected further increase in quality of proposals) versus breadth of coverage and funding of the largest reasonable number of investigators.

This dilemma can probably be most efficaciously resolved by determining, first, if the amounts and durations per investigator are equivalent to those for NSF (and NIH, in the case of animal and clinical studies) investigators in the cognate fields. If so, then, *as additional appropriations may become available*, over a moderate period of 3–5 years the amounts and durations could be increased incrementally (to increase attractiveness) *along with* increase in the number of grant awards (to broaden coverage of the priority research areas). The key for success is to increase appropriations to the program. Without such an increase, the program will be frozen into its current, truncated state; there are few, if any advantages of that for the program or for the nation's needs in the agriculture/food/environment sector.

As already pointed out, one of the aims of the program is to involve investigators throughout the scientific community—irrespective of the institutional affiliations, home departments, or disciplinary specialties of the scientists—in research questions especially relevant to the agriculture, food, and environmental sector. In addition, it is the aim of the program to make it attractive and available to those in the SAES and land-grant university systems. This has occurred (see table 3-3). The program has received proposals from investigators from traditional and nontraditional institutions (see table 3-3 for definitions) in almost exact proportions (79:21) for each of the past 10 years; only 1994 showed a slightly larger proportion of proposals from the nontraditional institutions (76:24). During this time, the program appropriations increased from $46 million to $103 million. Thus, as the funding increases, scientists from both traditional and nontraditional institutions are comparably attracted to it in proportional number. Equally positive has been the relative success of scientists from the two institutional types. Each has been funded to almost exactly the same extent (averaging 23.4 and 22.7 percent, respectively, over 10 years). This shows both comparable quality and competitiveness from scientists from the two institutional types.

These results have clear implications: NRICGP appeals much more strongly to scientists from traditional institutions than nontraditional (79:21 preference). Scientists submitting proposals are equally competitive irrespective of type of institution. Scientists from both types of institutions are comparably and proportionately attracted to the program, irrespective of funding level (the average amount and duration of grants has been generally constant throughout this period). A major way to involve more scientists from the nontraditional institutions is to increase appropriations. But, caveats are also in order. For example, it is quite possible that scientists from nontraditional institutions might be even more attracted to the program if average grant awards and durations were increased, given the "award sensitivity" of certain investigators, and given the relatively different award structures between the NRICGP and NSF (and NIH) programs.

[5] Calculated using data provided by the NRICGP office in determining the appropriation levels required if NRICGP grants were to be equal in direct costs to NSF grants.

	Traditional institutions[a]			Nontraditional institutions[b]				
Year	Requested	Funded	Percentage funded	Requested	Funded	Percentage funded	Total	Percentage from traditional
1985	2,054	342	16.7%	530	104	19.6%	2,584	79%
1986	1,562	374	23.9	424	104	24.5	1,988	79
1987	1,280	279	21.8	365	84	23.0	1,645	78
1988	1,230	292	23.7	318	78	24.5	1,548	78
1989	1,120	280	25.0	278	51	18.3	1,398	80
1990	1,363	316	23.2	391	66	16.9	1,754	78
1991	2,122	456	21.5	536	121	22.6	2,658	80
1992	2,342	624	26.6	537	148	27.6	2,879	81
1993	2,295	629	27.4	590	159	23.8	2,885	80
1994	2,666	634	23.8	837	199	23.8	3,503	76

SOURCE: U.S. Department of Agriculture, National Research Initiative Competitive Grants Program Office, 1995

[a] Traditional institutions include: 1862 Land Grant, 1890 Land Grant, Other Federal Research Laboratories, State Agricultural Experiment Stations, USDA/S&E Laboratories, and Veterinary Schools/Colleges.

[b] Nontraditional institutions include: individuals, private nonprofit, private-for-profit, private universities/colleges, and public universities/colleges.

As already emphasized, it is important for the health of the agriculture/food/environmental sector to attract the widest possible pool of investigators to do research relevant to the sector, to make them part of the knowledge generation system for the sector, just as has been done for the biomedical sector. So far, notwithstanding the several elements of USDA's research portfolio, the nation's scientists are not substantially attracted to or invited to participate in research for the agriculture/food/environment sector. NRICGP is the best, often the only, mechanism for doing this for the sector, just as NIH has been able to attract an exceptionally broad and talented pool of scientists for the biomedical sector.

The funds available are not sufficient to provide adequate and to fund adequately the qualified proposals for them. This is illustrated by the lower award amounts and duration, as discussed above; by the modest proportion of proposals that can be funded (21–27 percent during FY 1990–94[6]) and the inability to fund another 25 percent of the proposals judged to have high quality which merit funding; and the pressing need for this foundational research (22).

Thus, it is concluded that the funds available for NRICGP are distinctly insufficient for the overall program. This works to the detriment of the goals of the program, increases the frustration and lowers the productivity of participating scientists, and makes obtaining the necessary foundational knowledge more difficult and attenuated. None of this benefits the quality or security of the research system for the agriculture/food/environmental sector.

Some have suggested[7] that the decreasing availability of federal funds for competitive grant programs in the face of continued scientist interest and high-quality proposals is leading to a risk-averseness in making awards, with more risky and innovative research being funded proportionately less than more established approaches and subjects. Program managers for NRICGP do not believe that is occurring for this program. In addition, NRICGP specifically includes a program area for strengthening

[6] From Annual Reports of the NRICGP.

[7] See for example, *Washington Post*, 25 December 1994.

research capacity for institutions that have traditionally not received the same proportions of federal funding as more established institutions. These awards are of the riskier type, given institutional capacity and less grant-experienced investigators. From 11–19 percent of the program's awards have gone to these institutions, testifying to the willingness of the program to take these risks conditioned only by the same criteria as for all proposals (quality of the proposed research and its relevance).

As a management issue, it is important that additional funds be used by the program in a cost-effective manner. The program has "lean" staffing levels (17 scientists for $100 million of grants) and it economizes on administrators (having only three directors to manage six program divisions and the agricultural systems, and, in addition, one program director for the SBIR program). This compares favorably with other federal agencies. Even with this economical approach, because of the way work is deployed, it is estimated that current staff could handle an additional $25–50 million of funding. Thus, when funding for the program has been increased, there has been no difficulty managing the increased workload, including review of proposals and making timely allocations. Thus, "rate of absorption" of additional funds is not an issue.

Earmarking. Earmarking has unfortunately become part of NRICGP, and must be addressed with a view to its elimination. As context for this discussion, it is important to consider the rationale for the program. NRICGP has a very strong focus of connecting fundamental research and the resulting foundational knowledge to the missions of USDA and the contemporaneous issues facing the agriculture/food/environment sector. It does this in several key ways: the disciplinary yet mission-linked focus of its priority research areas; the cross-cutting programmatic themes that embrace these issues; the major emphasis on multidisciplinary research and mission-linked research (at least 30 and 20 percent, respectively, of the research funding must go to these two areas) along with the foundational research; the social and economic aspects of the sector, including rural life and development; and the major provisions in NRICGP for incorporating knowledge and technology transfer and their practitioners, including Cooperative Extension personnel, into the research programs. Further, the NRICGP staff in its implementation of the program has continuously emphasized in its announcements and in its review practices the need for relevance of the program to these issues. For all of these reasons, the program is closely and prudently connected to the issues of the sector, while emphasizing the necessary foundational knowledge that is broadly applicable to them. Thus, it cannot be reasonably concluded by any objective assessment that NRICGP is ignoring the needs of the agricultural sector and needs to have earmarks placed on its programs so that it pays adequate attention to those needs.

Some funds appropriated to NRICGP have been earmarked for specific issues and interests, in direct contradiction that these funds be awarded to the best science in high-priority areas relative to agriculture. Earmarking to fund local, specific research and/or facilities issues has long been a feature of Congressional appropriations for USDA's overall research portfolio. Earmarking makes the insufficiency of funds for NRICGP all the more onerous. Earmarking reduces the funds that can be competitively awarded to the fundamental studies for which NRICGP is specifically and predominantly designed. Significantly, earmarking substitutes contemporaneous, usually short-term political judgments for long-term scientific judgments of mission relevance and scientific merit. Two kinds of earmarks have occurred: administrative and Congressional.

In FY 1994 the Secretary of Agriculture earmarked $2.5 million to the U.S.–Israel Binational Agricultural Research and Development (BARD) program. This was the first time this kind of earmarking had been done by the administration of USDA. For FY 1995 Congress seized on this precedent and itself earmarked $2.5 million for BARD within NRICGP, dividing the funding among the NRICGP program categories.

Congress in FY 1995 earmarked $8,113,000 of the NRICGP appropriation for three *new issue- and management-oriented programs*—water quality, integrated pest management, and pesticide assessment. Prior to this time, funds had been appropriated to the six research program areas authorized by FACTA. This earmark originated in FY 1994 when Congress shifted more than $9 million to NRICGP while subtracting the same amount from a combination of the special grant funds for the generic, national programs for regional water research, regional IPM, National Pesticide Impact Assessment Program (NPIAP), and Global Change research.

To try to keep these FY 1994 funds as much as possible within the principles of NRICGP under these compromised circumstances, the NRICGP staff created four mission-linked programs—water resources assessment and protection (for water quality research), biological control (for IPM research), assessment of pest control (for NPIAP research), and UV-B monitoring; placed them within the relevant research priority divisions (Plants and Natural Resources and Environment) of NRICGP; solicited proposals for them and managed the proposals in the normal way; and made awards for work in these categories by using the normal peer-review process followed by competitively awarded grants. Interestingly, because the NRICGP office had already established "cross-cutting program areas" for both water quality and integrated pest management, and because UV-B monitoring fits neatly into the Natural Resources and Environment research area, earmarking these funds in 1995 was not even necessary.

The NRICGP management staff has been effective in connecting the program to contemporary issues in the agriculture/food/environment sector. Given this, simply registering Congressional intent to ensure work in these areas would very likely have been sufficient. Notwithstanding the positive efforts by NRICGP, the earmarking of these funds is an ominous portent because it provides a precedent for dividing these funds into issue-focused project funding. This defeats the purpose of NRICGP to support fundamental studies and, especially, to have an organized, managed integrity of the six program areas.

As noted at the outset, and as a final policy perspective, this earmarking is incongruous because of the unusually strong emphasis given by NRICGP to the issues and problems of the agriculture, food, and environment sector. To a large degree, NRICGP conceptually is a hybrid between the foundational programs of NSF and the applied research programs throughout USDA and its participating state institutions. Ironically, this mission-orientation of this program could be its "Achilles heel." This open connection of NRICGP with issues of the sector could, indeed, provide a quiet, convenient entry point and rationale to shift this largely foundational knowledge program to applications-oriented research. If that were to happen, the value of the program would be lost. And if the foundational purpose of the program were lost, it would be prudent to abolish the program rather than create an unnecessary redundancy with existing programs and simply leave a void in the foundational research area.

Attitudes toward NRICGP. A number of attitudes toward NRICGP are positive and supportive, while some are less so. Taken together, and recognizing that concerns can easily diminish support for appropriations, this mixture of attitudes contributes to the languid funding of NRICGP.

Some of the positive and supportive attitudes include the following. The positive response among research scientists has been strong and consistent, both in terms of submitting high-quality research proposals and in their advocacy for NRICGP. A wide range of commodity and user groups were early supporters of the proposals leading to NRICGP, and a number have continued their support, such as the wheat growers. Similarly, the SAES directors have steadily supported NRICGP, along with other elements of the agricultural research portfolio in their annual budget recommendations made through the National Association of Land Grant Colleges and State Universities. But it must be observed that

none of this support has taken on the force and immediacy found for support of biomedical, physical science, engineering and related programs such as for global climate change. Until that kind of impact is felt, support for NRICGP is likely to continue to be viewed as tepid or unimportant. In the face of this, the value of NRICGP in advancing science is amply demonstrated in a number of ways, one of which is illustrated during 1994–1995 by nine cover stories in *Cell, The Plant Cell, Nature*, and *Science*—four of the most significant peer-reviewed journals for biological research—featuring research funded by NRICGP.

Of particular importance, Congress has consistently supported NRICGP. Further, Congress has recently been emphasizing basic research of the type that characterizes NRICGP. It is also giving steadily more attention and emphasis to competitively awarded research funding, of the kind that also characterizes NRICGP. And Congress has appropriated regular increases in NRICGP's funding to its current level of about $100 million. Congress has not, though, responded positively to increases proposed by both Bush and Clinton administrations for additional appropriations (up to $130 million for FY 1996).

There are also some less-than-positive aspects of support for NRICGP. Funding by Congress, as already noted, has not increased in the past three years. This is particularly disturbing given the erosion of purchasing power caused by level funding, making it particularly difficult for NRICGP to meet the objectives set for it by Congress itself. Funding earmarks, some by Congress and others by the administration, have further eroded NRICGP and show less than full support for the program. The positive support by the agricultural research sector is not as enthusiastic as might be expected. For example, and as already noted above, the NRICGP is included in the annual NASULGC recommendations as just one of several recommendations; while this may be appropriate given that all elements of the research portfolio are important, it being but one of several items does little to demonstrate the crucial importance of NRICGP. Some have criticized NRICGP, both directly and indirectly, because it does not specifically include Cooperative Extension. The criticism is not justified. NRICGP—in both the BA/NRC report and in the Congressional language of FACTA—specifically speaks to multidisciplinary and mission-linked studies, each of which relate directly to Cooperative Extension; further, both the BA/NRC report and managers of NRICGP encouraged Cooperative Extension to be part of multidisciplinary research teams, thereby further incorporating user perspective in the research and expediting application of research results. There is also the concern by both agricultural research and extension leaders that funding NRICGP competes with other funding, such as formula funding.

There are at least four distinct actions that are appropriate for the research/extension community and USDA. First, advocates for agricultural research and extension, including its leadership, must continuously understand and articulate the importance of foundational knowledge for the agriculture/food/environment sector, along with the more applied and specific research and application. Second, there must be comparable recognition that the overall research (and extension) portfolio is complex, that each element is important *including* NRICGP, and that support is needed for NRICGP, particularly because it is still a new, emerging program. Third, as a corollary, it is essential that the emphasis on NRICGP continue to be on foundational knowledge, that the emphasis not shift to applied studies on contemporaneous issues. Fourth, USDA and specifically the NRICGP staff should continuously show the relevance of NRICGP's knowledge development to topical issues. This should be done by illustrating the relationships between its studies and the issues and by continuously examining its portfolio to ensure that synergistic connections to agriculture/food issues obviously exist within its grant programs and awards. USDA's work to date in these regards has been effective, but it should also be continued and intensified.

Relevance of NRICGP to Issues in Agriculture

The relevance of NRICGP to major issues and challenges in the agriculture/food/environment sector is a key factor for establishing and evaluating the success of the program. NRICGP is relevant to the issues confronting agriculture when assessed by at least four criteria: (i) the central value of foundational knowledge for addressing key agricultural challenges; (ii) a central element in USDA's diversified research portfolio; (iii) the quality of the research proposed that is directly relevant to the challenges; and (iv) its direct relevance to key topical issues such as sustainable agriculture.

Value of foundational knowledge. The purpose of the program is to provide foundational knowledge by conducting fundamental research that establishes new principles, understanding, methodologies, and mission-linked research that aims at solutions to contemporary problems but that is also broadly applicable and thus has characteristics similar to fundamental research. As noted earlier, the priority research areas of NRICGP embrace the breadth of knowledge needs for the agriculture/food/environment sector. For example, the molecular and cellular biology, biochemistry, and physiology necessary for understanding insect and pathogen damage and control is addressed within the plant, animal, the environment areas; the biology and control of food-borne pathogens is addressed in the plant and nutrition areas; the understanding of biological and physical properties necessary for creating new products and processes is addressed in the plant, animal, and engineering/new products areas; and the social and economic analyses necessary to sustain rural communities are studied in the markets, trade, and policy area. Put another way, one of the most significant challenges in U.S. agricultural research is developing the knowledge needed to change from resource-based to knowledge-based agricultural production systems. In a very real sense, the program is directly relevant to the issues and challenges of the U.S. agricultural system.

Central element in USDA research portfolio. The program is a central, integral element in the overall federal and USDA research portfolio for the agriculture/food/environment sector. The program emphasizes foundational knowledge. For example, NRICGP funds plant breeders to understand the mechanisms of genetic variability and its usefulness in plant structure and disease resistance. But the program does not fund plant breeding; that is the responsibility of other parts of the portfolio and the private sector. As noted earlier, other elements of the portfolio include ARS, with its emphasis on basic and applied research that is nationally relevant; SAES and land-grant colleges of agriculture and allied subjects which do basic and applied research and focus on locally and regionally specific issues as well as generic national issues; the nationally applicable special grants which address major current issues; ERS and FS which emphasize economics and forest-related questions, respectively; and the Cooperative Extension system, which emphasizes developing applications and extending them to users, often in cooperation with SAES and ARS researchers. In addition, the private sector is a major research contributor, generally emphasizing technology development and application. NRICGP provides foundational knowledge relevant to all of these research participants. Each of these has its special roles to play. None can succeed well absent the others. The program is a key central element of this diverse research portfolio.

Quality of research. Quality of the research is increased by its peer evaluation and by seeking and insisting on connection to the issues of the sector. Various indicators have already been discussed and include: use of the criteria of scientific merit and relevance to issues for both peer review of proposals and award allocations; user and stakeholder workshops; scientific advisory committees; program announcements and panel composition that recognize the relevancy criterion; cross-cutting themes; openness to including additional topics in the program areas, such as soils and soil biology, which are closely related to resource productivity and protection.

All of this is commendable and should be continued. This insistence on relevance is further enforced by the specific inclusion of multidisciplinary research (required to receive not less than 30 percent of the funds) and specific opportunities for connection of the research to the extenders and appliers of research by encouraging their participation in the multidisciplinary research and in the category of mission-linked research (required to receive not less than 20 percent of the funds in FY 1993 and thereafter).

Direct relevance to key topical issues. NRICGP is directly relevant to key topical issues in the agriculture/food/environment sector. NRICGP secures this relevance to these issues by its subject area comprehensiveness; its requirement of relevance—along with scientific merit—for grant awards; its inclusiveness of and responsiveness to topical issues, such as biological control, water quality, and global change; guidelines for and management of proposal review and grant awards; and the continuing relationships of the program staff with users and stakeholders. This is demonstrated by the average of 75 percent (in a range of 66–83 percent) of all NRICGP funds during FY 1991–1994 allocated to cross-cutting themes—strategic areas—which, themselves, are broad categories of topic issues (discussed in a later section).

Sustainable agriculture provides an illustrative example. It has intrinsic importance as a research area and paradigm for the overall agriculture, food, and environmental sector, including rural areas. Reflecting this, Congress in FACTA requested that "the Secretary of Agriculture shall ensure that grants [from NRICGP]...are, where appropriate, consistent with the development of sustainable agriculture" (Title XVI, Sec. 1615, (b) (j)). Sustainable agriculture is defined in FACTA and discussed in chapter 4.

Clearly, sustainable agriculture needs foundational knowledge for all its facets. NRICGP's emphasis is such foundational knowledge. Examples of this needed knowledge include understanding the organismal and environmental biology of soil-borne organisms; understanding and using biological methods of pest management; understanding analytically the social and anthropological relationships between humankind and the land and water resources, and the factors that provide for self-sustaining rural communities; and understanding the *system* of sustainable agriculture and how the components interact.

NRICGP relates directly to sustainable agriculture. NRICGP staff review all proposals to determine their relevancy to the long-term sustainability of agriculture in general and to sustainable agriculture in particular. Estimates for FY 1995 awards are that at least $16 million of NRICGP's roughly $100 million budget will relate *directly* to core sustainable agriculture issues such as helping rural communities, sustaining natural resources, and decreasing the dependency of U.S. agriculture on pesticides. More than $14 million of the FY 1994 NRICGP research grants related directly to sustainable agriculture. Much more research also relates, such as molecular mechanisms of virus movement through plant tissues and resistance genes to bacterial pathogens, two discoveries that lie at the center of natural mechanisms for pest management in sustainable agricultural systems. Both, incidentally, have been featured as lead research findings in leading international research journals.

Some have sought to establish a sustainable agriculture relevancy protocol for research supported by USDA. Because foundational research is, by definition, research that aims to discover underlying principles permitting understanding of fundamental phenomena and is usually broadly applicable across a spectrum of more applied problems, it follows that relevancy protocol, for sustainable agriculture or other specific management or production systems, are not especially useful or appropriate for NRICGP. This was, indeed, the consensus view of a broad spectrum of scientists and policy analysts gathered to consider research supportive of sustainable agriculture (11). The review of NRICGP by the Board on Agriculture reached a similar conclusion (6).

Proposals relevant to sustainable agriculture must, like all proposals for funding by NRICGP, be investigator-initiated: responsibility for their content is with the investigators proposing the research. Thus, it is the responsibility of the investigators to ensure the proposals contain sufficient social, economic, cultural, rural development (and also biological) aspects to meet the research needs. The program judges the proposals on their scientific merit and relevancy; it does not try to force a particular form of relevancy, which would be antithetical to the usual traditions of investigator responsibility and freedom.

In addition to all of the above, the NRICGP staff have taken a number of steps to ensure that research for sustainable agriculture is intrinsic to NRICGP. This has included lengthy discussion with advocates for sustainable agriculture to understand and incorporate their concerns; specific inclusion into NRICGP's call for proposals and instructions to peer reviewers of the FACTA definition of sustainable agriculture; FACTA's emphasis on research to advance sustainable agriculture; and incorporation of relevance of proposed research to the long-term sustainability of agriculture into the proposal evaluation factors. Workshops with users and stakeholders have also included an emphasis on sustainable agriculture.

Relationships between Program Areas and Funding

It is important that there be supportive relationships between the program areas and the funding available. Within the limited funds, this appears to be the case. These relationships can be addressed in at least five ways: (i) financial coverage of the priority research areas; (ii) responsiveness to new issues and related research questions; (iii) cross-cutting themes in relation to the priority research areas and the issues of contemporary agriculture; (iv) multiple disciplines and priority research areas; and (v) capacity for funding the mix of multidisciplinary and mission-linked grants.

Financial coverage of priority research areas. FACTA authorized six high-priority research program areas, represented organizationally by the current six divisions of NRICGP. Each has now received funding, with funding for processing for value-added products and markets, trade, and rural development starting in FY 1992 (see table 3-2). Financial coverage of all the areas is commendable. However, the amounts are insufficient for the program's scope and importance, as documented in the previous section. For example, the size and duration of awards is already less than desirable for individual grants; further, the appropriations are insufficient to fund all of the highest priority proposals and to attract even more of the nation's scientists to the program. To give some estimate of the shortfall in funds for adequate coverage of the six areas, just based on current interest of scientists, NRICGP staff have estimated that providing grant awards comparable to NSF and to fund the same highest priority proposals would have taken an additional $24 million in FY 1994.[8]

As noted earlier, NRICGP senior staff estimate that the next 25 percent of the proposals (after those already funded) could be funded without any reduction in quality of proposals funded, bringing to about 48 percent the submitted proposals worthy of being funded. Further, relative to plant systems and animal systems, the four other priority research areas of natural resources and environment; nutrition, food quality and health; markets, trade, and rural development; and processing for added value are substantially underfunded.

Although there is financial coverage of the priority research areas, the funding for the areas is not sufficient either to fund all qualified proposals or to provide proportionate funding for the

[8] Estimates by NRICGP staff factoring in the differences caused by the NRI overhead rate of 14 percent and an NSF overhead rate of 50 percent on direct costs. Thus, a $100,000 NRI award (with 14 percent overhead rate) is comparable to a $129,000 NSF award (with a 50 percent rate).

six areas based on funding for the areas of plant and animal systems.

Responsiveness to new issues and related research questions. There have also been significant additions to NRICGP, especially in FY 1994.

Agricultural systems research, a multidisciplinary, mission-linked program that relates to ecological and socio-economic principles and practices in agriculture (such as integration of field-farm-watershed and production-processing-marketing studies), was added as a program element in 1994. It was established by the NRICGP staff because they realized that some areas of key importance to sustainable agriculture, and to agriculture and environment more generally, were not given sufficient emphasis by the extant program categories. Specifically, there was determined to be insufficient opportunity for funding research that was multidisciplinary. Although not a division as an organizational unit, the agricultural systems category is listed equivalent to other program areas to emphasize the importance of it for the entire program (14).

Soil biology and ecosystems were established in 1994 as programs within the natural resources and environment division; the ecosystems program was expanded to include aquatic ecosystems.

This steady development of NRICGP is commendable. However, new program areas cannot be added unless additional funding is provided. Without additional funding, the NRICGP will be threatened with too many grants of limited duration and funds, two problems that plagued the earlier competitive grants program.

Cross-cutting program areas. Because the primary purpose of NRICGP is to fund foundational research *in relation to the missions* of USDA and the agriculture/food/environment sector, NRICGP is also managed to provide coverage of major "cross-cutting program areas" that address contemporaneous issues and concerns. A significant portion (ranging from 66 percent in FY 1992 and 1993 to 88 percent in FY 1994) of the grant awards are directly related to these issues and concerns (see table 3-4). It is also true that results from other fundamental

Program Area	1991		1992		1993		1994	
	Awards	$ (000)	Awards	$ (000)	Awards	$ (000)	Awards	$ (000)
Plant Gnome	77	10,500	95	12,309	91	12,126	104	11,739
Forest Biology	53	6,428	57	7,164	50	6,340	52	6,993
Global Change	79	9,059	83	9,400	86	9,218	93	10,575
Sustainable Agriculture	76	7,059	97	10,640	100	10,142	102	14,668
Animal Genome	27	4,526	33	5,661	26	4,096	25	3,908
Animal Health	53	8,870	72	11,213	69	10,693	75	9,964
Water Quality	33	4,369	37	4,629	33	4,325	54	7,395
Food Safety	NI	NI	NI	NI	31	3,973	28	4,343
Integrated Pest Management	NI	NI	NI	NI	NI	NI	153	15,611
Total awards to program areas	398	50,811	474	61,016	486	60,913	686	85,196
Total awards to entire NRI	590	69,204	777	92,139	790	91,814	833	96,630
% in cross cutting		73%		66%		66%		88%

SOURCE: U.S. Department of Agriculture, National Research Initiative Competitive Grants Program Office, 1995.
NI, not identified.

studies will, over time, be directly relevant to these areas, as the principles they elucidate form the basis for applied research and direct applications. Based on the amount of funds directly related to cross-cutting program areas, research funded by NRICGP is obviously relevant to contemporary issues in agriculture.

Multiple disciplines and priority research areas. Research challenges for the agriculture/food/environment sector involve, to a large degree, topics that must be addressed in a multidisciplinary fashion. Research is often done, for good reasons, from the perspective of single investigators, from the perspective and using the methodologies and paradigms of a single discipline. However, this is inherently limiting in addressing the more multifaceted dimensions of key phenomena in the sector, such as pathogenesis, environmental stress, prey-predator interactions, environmental and landscape biology, and ecosystem phenomena. For these reasons, multidisciplinary research was given specific and distinctive emphasis in the original BA/NRC report and in the Congressional authorization of NRICGP.

A specific concern is sometimes raised regarding the role of economics in research areas. The markets, trade, and rural development program area is obviously relevant to economic issues. Further, certain biogeophysical and technology areas are also directly relevant, such as ecosystems (especially if dealing with optimization and natural resource valuation issues) in relation to value-added questions. Some have urged that social scientists, and specifically economists, must be part of certain kinds of proposals. Such a mandatory requirement is inappropriate. The entire philosophy of a competitive grants program is to provide opportunity for grants, and study, within a program area, contingent upon having high-quality proposals that have relevance, rather than strictures on what disciplines must, or must not, be included. It is of course true that the highest quality and relevance might, indeed, require economics as part of the analysis or participation by economists on the research team (as might be true for multidisciplinary proposals), but this is best established by the review process, not as a stricture at the beginning. Interaction is forced only in the agricultural systems program, and even then the disciplines or subjects are not specified.

A caveat is in order, however. Desirable as this peer-driven system is, it is essential that peer review of the proposals involving multiple disciplines involve scientists from those disciplines—and especially scientists who are expert in multidisciplinary work. For example, when social science topics are part of a biologically oriented proposal, social science disciplines should be involved in its review, along with the requisite natural science expertise, to ensure that the social science components are considered fully by experts in those fields, not by other scientists making judgments on their behalf.

It is thus evident that the present system provides ample opportunity for investigators to form into teams as necessary and that there is ample opportunity, specifically, for social scientists to participate in a broad range of research areas. Further, the peer-review process is appropriate for determining the relevance and quality of proposals where social science is, or could advantageously be, an integral part of the research plan.

Capacity for funding the mix of multidisciplinary and mission-linked research. FACTA specifies that not less than 10, 20, and 30 percent of NRICGP funds, respectively, for FY 1991, 1992, and 1993 and years thereafter, are to go to multidisciplinary research; not less than 20 percent to mission-linked research; and not less than 10 percent for research and education strengthening. Table 3-5 shows that USDA has distributed the funds generally consistent with this intent. This is noteworthy, considering that appropriations have not increased or even closely approximated the authorization levels for the program, and it is especially significant because the increase in percent of multidisciplinary grants included in FACTA was predicated based on corresponding increases in funding.

Research Dimension	1991		1992		1993		1994	
	$ (000)	%	$ (000)	%	$ (000)	%	$ (000)	%
Basic Fundamental	50,985	74	64,501	70	61,911	67	60,677	63
Mission-linked	18,219	26	27,638	30	28,903	33	35,955	37
Multidisciplinary	19,781	28	22,872	25	31,513	34	26,345	27
Single discipline	49,723	72	62,267	75	60,301	66	70,287	73
Research Strengthening	7,450	0	16,053	186 *	17,152	209 *	16,874	211 *

SOURCE: U.S. Department of Agriculture, National Research Initiative Competitive Grants Program Office, 1995.
*Number of grants

Implementation Issues

NRICGP is running well, given the constraints of funds and the high and varied demands on it. Major changes in its operational features are not necessary. There are, however, several related issues that must be considered. Some have already been considered earlier, but only briefly. Others, such as a proposed strategic research and applications plan, are derived by synthesis from a number of observations and are discussed at greater length.

Understanding and emphasizing the role of fundamental research, foundational knowledge, and competitively awarded research grants for the agriculture/food/environment sector, including contemporary issues. As already noted, there is a continuous need to make clear the contribution of foundational knowledge and fundamental research (including the more basic aspects of mission-linked research) for all aspects of the sector. This applies especially for contemporaneous issues such as sustainable agriculture and social and economic quality of the rural and farming sector. This requires diligence and initiative by the scientific community as a whole, and not just by the NRICGP staff. It also requires understanding and confidence by advocates of topical issues.

Consistent with this, there is increasing support in Congress and nationally for sustaining (even increasing) federal support for fundamental research; for determining and then focusing what the federal government should support, in relation to what the states and private sectors should rightfully support; for cutting "pork barrel" projects away from federal funding; and for making grant awards through competitive processes, whether for fundamental or mission-linked research.

Understanding the role of NRICGP in securing foundational (and related mission-linked) knowledge within the portfolio of research for the agriculture/food/environment sector. NRICGP is one of the major elements in the portfolio in securing this foundational and related mission-linked knowledge. It is not the only element: ARS, ERS, and FS, and key elements of the overall SAES program, are other elements. But NRICGP is a key element, particularly because it is the major entry point for *all* the nation's scientists to participate in research for the sector. Further, NRICGP cannot stand alone. Its work must be an integral part of the fundamental-applied research continuum; and it must also be related to applications. Both are accommodated in NRICGP because of the emphasis on multidisciplinary and mission-linked research.

Establishing unified strategic research and applications plans for contemporary issues. One of the challenges for the overall research and applications/extension portfolio for the agriculture/food/environment sector is the need for connecting and expeditiously applying research results from across the sector to key, vexing national challenges. The most obvious way to meet this challenge is to create a unified strategic research and applications plan for key contemporaneous issues. Such a plan would identify the key knowledge development questions, and

hence the several research and application elements, needed to address an issue. The plan would describe how the research and application elements would be combined and integrated meaningfully to take advantage of comparative strengths and expertise, and link research results to desired applications outcomes and preferred mechanisms. A crucial component of the plan would be to identify desired outcomes and anticipated time frames. Funding, including relevant federal funds, for dealing with a specific issue could then be optimized for application within the context of the overall strategic plan. Recent examples of such federal funding have been those for pest management, sustainable agriculture, genome research, and water quality.

Fundamental research and foundational knowledge may be expected, usually, to be part of this. Thus, NRICGP would usually be a part of these plans along with the other relevant elements of the research portfolio, including usually ARS, SAES, the private sector, and often other cognate agencies (such as, for example, EPA, the U.S. Geological Survey, ERS, and FS). Similarly, the extenders of knowledge and technology transfer entities would be a part, including especially the Cooperative Extension system and various USDA agencies.

The purpose of the plans would be to show how all elements fit into a comprehensive strategy designed to "deliver the goods" to major issues and what their principal contributions would be expected to be. The purpose of such plans would *not* be to specify how (largely) autonomous researchers and extenders would function. At present, there is no evidence of such strategic plans, except informally and through traditional ways of working among the elements.

These plans would be an effective venue for addressing the key question: Is the current system for dealing with contemporary issues adequate, or is a holistic, focused approach preferred? It is certainly incorrect, unreasonable, and unwise to ask any single part of USDA's overall research program—such as NRICGP—to carry by itself a preponderant share of the research burden for a particular topic. This narrow focusing on to just one part of the folio—either NRICGP or another—is especially inappropriate because so many different components apply to a single issue. It is important to harness all of them. It is more appropriate to ensure, first, that the various dimensions of the topic are covered by one or more elements *within the various USDA research programs* and, second, that there are no gaps or unnecessary redundancies and duplications of research coverage. This means, for example, that the foundational questions have a place in the NRICGP portfolio *and* that relevant priorities are also established for other elements of the portfolio (ARS, states, cooperators). Applied research results should be drawn from throughout the overall USDA program (and from others agencies and sources, where relevant knowledge is available), integrated, and transferred to the relevant applications and the user organizations. The key role for Cooperative Extension in this knowledge and technology transfer process is very important and must not be underemphasized. Taken as a whole, this would result in an integrated, strategic research and applications plan where knowledge and technology transfer is connected interactively with the research process. Put differently, all elements of the research and applications portfolio could be considered together and function collaboratively in relation to key issues and each would have its own place in the issues.

It might be argued by some that such a strategic plan is already in place, especially with the array of federal-state cooperative arrangements, collaborations between ARS and SAES scientists, and relationships among scientists. Many observers, as evidenced by the persistent critiques of the agricultural research system, would argue otherwise. The planning done by the SAES and extension systems approximate in certain ways these plans, but they are not inclusive of all elements of the portfolio. The planning of the Joint Council does not address the agency focuses for the proposed strategic plans.

It might be argued by others that such planning must be (or at least preferably should be) from the "bottom up," from the scientists and

extenders, not imposed from "top down." Establishing research approaches and specifying research plans is most appropriately done by scientists and evaluated and decided upon (for specific funding, for example) by scientific peers. No one else has the expertise or insight to evaluate the quality and methodologies of a research plan. This kind of planning should always be from the "bottom up." However, establishing issue areas for emphasis is partly, but not solely, a scientist's responsibility. It is very much a "top down" obligation for those charged with larger social responsibilities, such as research managers, experiment station directors, Congress, and society as a whole. Similarly, establishing a strategic research and applications plan is a responsibility for these persons, combined with the expertise and insight of the scientists and extenders and appliers. In any event, developing these plans would very much involve the research and application practitioner/leaders relevant to the issues, so they would be, to a large extent, "bottoms up."

In making the strategic plans, the six priority research areas established by FACTA should be used as the template and framework for setting out the research needs. The research needs can be further correlated with the cross-cut areas established by NRICGP, which themselves directly relate to the great proportion (80–85 percent) of the NRICGP program. The reasons for using the priority research areas are several: the six priority research areas cover the entirety of research relevant for the agriculture/food/environment sector; they have proved effective and workable as a framework for planning and managing research programs; they relate to major issue (cross-cutting) areas; and they correspond well to the purposes for USDA's research as set forth by Congress.

Sustaining the emphasis on foundational knowledge. It is not appropriate to force NRICGP into funding applications-oriented research, such as sustainable agriculture research. Other programs have been established for that (such as the Sustainable Agriculture Research and Education program), and other organizations are more appropriate for that (such as the SAES system and Cooperative Extension). Conversely, it is not appropriate to ask issue-related research, such as that for sustainable agriculture, to carry major fundamental research responsibilities (even though there is much intermixing in both cases). Such issue-specific research is more appropriately funded separately, as it currently is.

Specific comment should be made about the proportion of mission-linked research to be funded by NRICGP. As noted earlier, mission-linked research was included in the original formulation of NRICGP. This was done to provide a place for studies that more closely connected to mission applications having characteristics of fundamental studies. This strengthens the continuum from foundational knowledge to more applied studies. Inclusion of mission-linked research was not meant to take from or be preponderant over fundamental research.

The initial amount of 20 percent for mission-linked research was believed appropriate to make the connections but not diminish the emphasis on foundational knowledge. More than 20 percent (such as 30–50 percent) of mission-linked research would be inappropriate and destructive to the purpose of NRICGP. It would be inappropriate because there are many places in the research portfolio where mission-linked work is emphasized (including the ARS, SAES, and special grants) and because NRICGP is the only place in the portfolio that emphasizes foundational studies in relation to all of the nation's scientists. And it would be destructive because there is already insufficient funding in NRICGP to cover its priority research areas and fund qualified proposals.

Sustaining the openness of NRICGP to all qualified scientists. A major feature of NRICGP—and a major advantage of it for USDA's mission—is NRICGP's openness to all qualified scientists, to providing opportunity for all these scientists to participate in addressing the agriculture, food, and environmental challenges of the nation. There is no evident threat to this feature of NRICGP. However, nothing should be

done to diminish this important feature. Major actions need to be taken to expand further these opportunities.

Expanding the means for addressing the research and technology needs of the future. At present a number of mechanisms are available for addressing these needs, several of which have been emphasized by the BA/NRC report and NRICGP as established by Congress in FACTA. These mechanisms emphasized in NRICGP include multidisciplinary research (in addition to the single disciplinary research which justifiably continues as a dominant mode), bringing extenders into the research programs (as in the mission-linked studies), and strengthening research capacity. FACTA also gives desirable emphasis to technology transfer and encourages positive relationships between, for example, NRICGP, SBIR, and the AARC (Alternative Agriculture Research and Commercialization Center, discussed in another chapter). Creation of strategic research plans would be helpful in addressing these future needs. All of this should continue to be emphasized. In addition, conducting multidisciplinary research and addressing multidiscipline and multispecialty issues such as sustainable agriculture, pest management, and water use and quality are relatively new approaches for researchers in the agriculture/food/environment sector. It is reasonable that continuing, special attention be given to improving ways to evaluate research for them, such as by expanding peer review of research proposals to include panels with expanded technical expertise and/or user and stakeholder expertise.

Emphasizing purposes and guidelines. Although the purposes for research established by Congress in FACTA are already part of research proposal solicitation and peer review by NRICGP, it is important to continue to emphasize them because they are national policy.

Relating to stakeholders and clientele. As already emphasized in several ways, this is a key challenge for NRICGP, just as it is for any program. Continuing and expanding stakeholder and client relationships, and particularly for commodity and rural economic development constituencies, is a major challenge for NRICGP, made easier by the major work it has already done.

Reexamining the organizational location of the NRICGP office. It is reasonable that an agency establish its own organizational and management system for its programs. However, it is also reasonable to examine the organizational location of NRICGP within USDA. The program is administratively located within the Cooperative State Research, Education, and Extension Service (CSREES). This location is appropriate in the sense that the CSREES funds *extramural* research (in contrast to the ARS as an *intramural* research agency) and because NRICGP is cooperative with the participating research organizations and that many of those are in the state agriculture/food research and extension systems (the primary agencies in the CSREES). Also, these beneficiary organizations should thus have a strong sense of the importance of the program and be strong stewards for its effective management and equally strong advocates for its continuance.

However, the mission of NRICGP very much transcends both ARS and CSREES. It relates to *all* scientists doing fundamental research and related mission-linked research. It relates to the entirety of the responsibilities of the Under Secretary for Research, Education, and Economics. Indeed, it goes beyond the Under Secretary's responsibility within USDA because it also relates to the FS, Natural Resources Conservation Service, the Animal and Plant Health Inspection Service, and other units of USDA, and to myriad scientists not directly within agricultural units *per se*. As such, it is not wholly appropriate for the program to be within a single research agency of USDA (such as CSREES or ARS). Rather, a more appropriate location to remedy this situation is to have it be a separate, independent office reporting directly to the Under Secretary.

Financial Issues

Resolving affirmatively several key funding issues is essential if NRICGP is to flourish as intended.

Resuming continued growth of the appropriations. The upward financial growth of the program must be continued, irrespective of external budget strictures, if there is to be even the possibility of securing the necessary foundational knowledge critically needed by the sector in the foreseeable future. There is much obvious need and, as Chapter 6 shows, research is a wise financial and public investment, given the high returns on the investment. This requires that Congress meet more closely, and preferably exceed, the funding increases requested by the Administration.

Increasing the proportion of funding to key areas. All of the priority research areas need additional funding. In particular, though, as additional appropriations are made, the proportion of funding should be increased for the research areas of markets, trade, and rural development; nutrition, food safety, and health; and processing for value-added products. Nutrition, food safety, and health is a particularly important area. Funding was provided for the other two areas after NRICGP was started, and thus their funds are limited. Furthermore, these latter two areas relate directly to key national issues: the social and economic vitality of rural communities and new products and processes. The extent of additional funding should be determined by NRICGP staff relative to the quality of proposals.

Stopping earmarks. Earmarking has been discussed in earlier sections, as has the view by some that NRICGP can be seen as a source of discretionary funds. Both should be stopped, as matters of national policy and in fairness to the critical needs for which NRICGP was designed.

Topical, contemporaneous issues are very important, such as sustainable agriculture, water quality, genome research, and pest management; internationally oriented research could also be included, given global concerns for food security and its effect on U.S. agriculture. However, it is inappropriate to redirect funds for fundamental research (NRICGP) away from generating essential foundational knowledge especially when other funds and mechanisms are already available for the intended research. Further, earmarking by USDA or Congress is contrary to best practices for research grants and antithetical to a peer-reviewed program where the reviews are based on the merits of scientific quality and relevance to the issues. Indeed, NRICGP has strong evidence that scientists are, themselves, strongly responsive to the topical issues relevant to their research. For example, with the emphasis on food safety in the FY 1994 proposal solicitation, the proportion of proposals and of grant awards for work on *E. coli* in food increased several-fold compared with the FYs 1991–93.

Increasing collaborations with other federal agencies. The collaboration between USDA's NRICGP and cognate programs in other agencies, such as NSF and DOE, is commendable. It should be continued and expanded to other agencies, such as Department of the Interior and EPA, where the interests of those agencies and USDA are similar. This mutual interest of related departments leverages the effect of federal funding, and encourages more effective and efficient federal funding. As additional funds become available, these collaborations should be increased.

Discriminating between national special grants programs and NRICGP. There are a number of areas appropriate for nationally focused special grants programs which bring basic and applied research (sometimes with extension involvement) to bear on key national issues. These areas and issues include sustainable agriculture, water quality, pest management, and the like. The emphasis of these mission-linked and often applied programs is compatible with the emphasis for NRICGP. But these mission-linked issues ought not to be subsumed by NRICGP. They should be placed inside other programs or into special grants. Being clear about objectives for the special grants programs, and having realistic expectations for what the outcomes will be from their funding, is impor-

tant. That clarity is obscured when special grants are blended with NRICGP, as has been done by some of the earmarks. It would be better for both the special grants and NRICGP to have the two programs—and the issues to be addressed—kept organizationally separate, along with seeing them as interactive elements in the strategic research plans discussed in the previous section.

Rationalizing indirect (research support) cost rates. At present there is one set of research support (indirect) cost principles and rates for NRICGP and another for all the other federal competitive grants programs. There is no policy reason why this should continue. The principles and rates for NRICGP should be the same as for the related federal programs. The reasons for this different rate may be understandable because of several distinctive features: USDA's longstanding partnership with state agricultural experiment stations; a long history of collaborative and cooperative arrangements; and the interest of faculty and their research managers in securing as much money as possible for research, and not providing for the necessary research infrastructural support. Those reasons may still be valid for formula funds to SAES and to cooperative agreements. But NRICGP grants are not in either category. Further, just as the lack of growth of appropriations for NRICGP by Congress is retarding the future of the program, the capping of the research support (indirect) cost rate at the arbitrary rate of 14 percent has made substantial difficulty for non-federal research partners. Indeed, this capped rate, which is far below the recovery of even nominal indirect costs, has effectively chilled, and in some instances precluded, the participation by scientists who are most at the leading edge of the foundational knowledge which the program seeks. Furthermore, the 14 percent has little bearing on actual conditions; it is simply a calculated rate from nominal ARS research administration costs. A more appropriate rate would be to follow current practice for other agencies, which involves capping administrative cost recoveries and conducting the normal indirect research cost negotiation process for all other costs, and Congress could so specify.

Sustainable Agriculture Research and Education 4

Two major components of the research title, as changed by Congress, address sustainable agriculture. First, the purposes applicable to the entire research title (discussed in chapter 2) emphasize sustainable agriculture. The purposes emphasize that all federally funded agricultural research and extension of USDA "be designed to, among other things, ...enhance the environment and natural resource base upon which a sustainable agricultural economy depends...enhance the long-term viability...of the food production and agricultural system...[and] enhance the quality of life for farmers, rural citizens, and society as a whole..." Notwithstanding the key importance of these provisions, this aspect of sustainable agriculture has not been emphasized here because of time constraints and because the General Accounting Office (GAO) published a study of USDA's management of the sustainable agriculture program in 1992 (31).

Second, as a continuation of Congress' interest in sustainable agriculture, it established through FACTA—in Subtitle B—the Sustainable Agriculture Research and Education (SARE) program as a successor to the Low-Input Sustainable Agriculture (LISA) program addressed in the Food Security Act of 1985 (the 1985 farm bill).

The purposes established by Congress in FACTA for SARE in this subtitle are "to encourage research designed to increase knowledge concerning agricultural production systems that:

1. maintain and enhance the quality and productivity of the soil;
2. conserve soil, water, energy, natural resources, and fish and wildlife habitat;
3. maintain and enhance the quality of surface and ground water;
4. protect the health and safety of persons involved in the food and farm systems;
5. promote the well being of animals; and
6. increase employment opportunities in agriculture."

In addition Congress reaffirmed in FACTA the definition of sustainable agriculture which it first established in the National Agricultural Research, Extension, and Teaching Policy Act of 1977 as follows:

1. "satisfy human food and fiber needs;
2. enhance environmental quality and the natural resource base upon which the agriculture economy depends;
3. make the most efficient use of nonrenewable natural biological cycles and controls;

4. sustain the economic viability of farm operations; and
5. enhance the quality of life for farmers and society as a whole."

Sustainable agriculture involves a *systems* approach, which Congress emphasized by establishing integrated crop management and integrated resource management as key components of this subtitle. It defined them as:

> "an agricultural management system that integrates all controllable agricultural production factors for long-term sustained productivity, profitability, and ecological soundness" and

> "livestock management which utilizes an interdisciplinary systems approach which integrates all controllable agricultural production practices to provide long-term sustained productivity and profitable production of safe and wholesome food in an environmentally sound manner."

When the purposes and definitions are taken together, it is particularly significant to note that sustainable agriculture includes three essential components: 1) agricultural production and productivity; 2) conserving, enhancing, and sustaining the natural resource base on which "the agricultural economy depends," including general environmental quality; and 3) the economic and social quality of farmers and farming. It is the efficacious combining of these three components that characterizes sustainable agriculture.[1]

Congress has been interested in sustainable agriculture since it devised the 1977 definition quoted above. This interest reflects emerging recognition of degradation of soil and water resources; the adverse impacts of chemical pesticides on environmental and human health; the steady decline of the economic and social vitality of the rural and farming sector; steadily decreasing farm numbers and growing evidence of increasing proportions of larger farming operations and part-time farmers; and increased competitiveness in agricultural production. Congress also aimed to address the unease of observers who argued that these concerns have received only limited attention from USDA and the land-grant university and state agricultural research system, if not outright neglect (23). This concern was reflected in the 1985 Farm Bill by Congress' intention that USDA determine how to do more research to preserve natural resources and environmental quality concurrent with ensuring agricultural productivity. USDA responded by giving increased attention to alternative agriculture,[2] including establishing the LISA program in 1988. Congress appropriated $3.9 million for the new program. During this time, also, the Board on Agriculture published a major study on sustainable (alternative) agriculture (4).

A particularly significant feature of the SARE program deserves special comment: specific provisions for administering and managing the program encourage, and enforce, the collaborative nature of the research-application process. Although this pairing has long been a feature of the agriculture research and application (extension) system, it is given new force and cogency by the SARE program. The key feature is a set of regional administrative councils that manage the SARE program and are to be composed of "farmers utilizing systems and practices of sustainable agriculture," agribusiness, "nonprofit organizations with demonstrable expertise," "state departments engaged in sustainable agriculture programs," and the customary array of leaders from the federal and state agricultural research and extension systems. These regional councils are responsible for project review, selection, and recommendations for funding of the grants to be awarded. A national advisory council, also established by FACTA, is comparably composed, and makes recommendations for

[1] Many of the conflicts and contentions related to sustainable agriculture arise because one of these three components is emphasized at the expense of the others. The three components must be considered together, in an integrated fashion, in order to fully understand their interactions, congruences, and synergies.

[2] These concerns were also marked by a range of titles and descriptions for what was intended: organic farming, alternative agriculture, and sustainable agriculture are just three of the names used, even though each means something considerably different from the others.

project approval and funding to the Secretary. Thus, the users of research are centrally involved in guiding the research program and full partners in it. This "market pull" for the SARE program contrasts with the "market push" of research findings separated from application.

IMPLEMENTATION

Congress established in FACTA three separate but interrelated programs: Chapter 1: Best Utilization of Biological Applications; Chapter 2: Integrated Management Systems; and Chapter 3: Sustainable Agriculture Technology Development and Transfer Program. Each is discussed in turn below.

For this subtitle, Congress in FACTA authorized a total of $80 million to be divided among the chapters as follows: $40 million for Chapter 1; $20 million for Chapter 2; and $20 million for Chapter 3. Appropriations, however, have been substantially less. The LISA program, which preceded SARE, received appropriations for FY 1988, $3.9 million, (its first year of appropriations) and for FY 1989 and FY 1990, $4.5 million each year. SARE received $6.7 million for each of the first three years, FY 1991–1993. Authorization of the SARE program was accompanied by a substantial percent increase in funding, emphasizing Congress' commitment to sustainable agriculture. For FY 1994, $7.7 million was appropriated for SARE, and funding was first provided for Chapter 3, the so-called training program, at a level of $3.1 million. For FY 1995, SARE appropriations were $8.1 million and training appropriations $3.5 million. No funding has been provided for Chapter 2, and it is not likely that this chapter will receive funding in the foreseeable future. There have been no earmarks, sequestrations, or special requests for any of these appropriations.

Four major general implementation steps have been taken. First, SARE has been administratively located and supported within the Cooperative State Research Service (now the Cooperative State Research, Education, and Extension Service, or CSREES), as was the LISA program before it. Given the intended extramural character of both LISA and SARE, this administrative location is appropriate. When the extension-based national training program (Chapter 3) was funded, a new office of Sustainable Agriculture Programs was established in CSREES and a director appointed effective February 1995. Second, the National Sustainable Agriculture Advisory Council, stipulated in FACTA, was established (see below in discussion of Chapter 1). Third, an administrative advisory group has been evolving for the Office of Sustainable Agriculture Programs. Its membership includes two representatives of each SARE region and representatives of the Agricultural Research Service (ARS), Natural Resources Conservation Service (NRCS), and the Environmental Protection Agency (EPA). This senior-level attention to sustainable agriculture is a positive development. Fourth, an inter-agency working group was established in August 1995 to advance sustainable agriculture research and extension throughout USDA. This development is discussed further in the section below.

Chapter 1: Best Utilization of Biological Applications

Appropriations for the SARE program are summarized above. In addition, a related program for Agriculture in Concert with the Environment (ACE) was jointly established by USDA and the EPA in 1991. It is a grant program to fund projects competitively that focus on pollution prevention in agriculture and on environmental and ecological aspects of agriculture, purposes complementary to and supportive of those for SARE. The ACE program is discussed concurrent with SARE, with which it is most closely associated. Funding of the companion ACE program derives from USDA and EPA on a 1:1 matching basis. For FY 1995, a total of $2.0 million was available.

The purposes of SARE include conducting "research and extension projects to obtain data, develop conclusions, demonstrate technologies, and conduct educational programs that promote

the purposes...including...projects that (1) facilitate and increase scientific investigation and education in order to [among other things] reduce, to the extent feasible and practicable, the use of chemical pesticides, fertilizers, and toxic natural materials in agricultural production; improve low-input farm management...; promote crop, livestock, and enterprise diversification; and (2) facilitate the conduct of projects in order to [among other things] study farms...using farm production practices that rely on low-input and conservation practices; take advantage of the experience and expertise of farmers and ranchers through their direct participation and leadership in projects; transfer...information to farmers and ranchers concerning low-input sustainable farming practices and systems; and promote..." partnerships among the various participants and organizations relevant to sustainable agriculture.

The SARE program is carried out through its own competitive grants program organized and managed by the four regional administrative councils authorized by this chapter.[3] Each regional council is composed of representatives of the relevant federal and state agricultural research and extension agencies (such as ARS, CSREES, state extension service, state agricultural experiment station [SAES], NRCS, state agriculture departments engaged in sustainable agriculture), farmers involved in sustainable agriculture, agribusiness, state or U.S. geological survey organizations, and other persons knowledgeable about sustainable agriculture. Each regional council receives an equal amount of funding ($1.7 million in FY 1995[4]) for allocation on a competitive basis to research and extension projects in the region. Each regional council establishes the priority areas for its emphasis and issues a call for proposals; preproposals may be invited. The technical and scientific merits of each proposal are evaluated by a technical committee established for this purpose by each regional council, and written and numeric evaluations are provided by the committee to the council. The regional council combines these evaluations of technical and scientific merit with its own evaluation of the relevancy and merit of the proposals for advancing sustainable agriculture goals. Recommendations for funding are forwarded to the National Sustainable Agriculture Advisory Council which makes recommendations to the Secretary through the CSREES for projects suitable for funding. As a practical matter, the decisions by the regional councils are supported by USDA except in isolated and special cases. The ACE program is also administered through the regional councils using the same mechanisms, and the same technical committees for evaluating the proposals.

A review of the projects illustrates their breadth and type. Projects last up to two years (Northeast region) or three years (the other regions). Funding per project varies from $50,000 to $250,000. SARE/LISA grants averaged $76,800 between 1988 and 1992 and $95,600 in 1993; ACE projects averaged $71,500 and $61,600, respectively. Of the 2,169 proposals received for the SARE and LISA programs between 1988 and 1993, 367 (about 26 percent) were funded, 65 projects in 1993. In 1993, 178 projects were active, ranging from 58 for the North Central Region to 35 for the Northeast, with the Southern and Western Regions having 43 and 42, respectively. Consistent with provisions for the federal-state matching grants program, the projects require a nonfederal match of not less than 50 percent of the project expenditures. These projects received $27.9 million in

[3] The four regions correspond to the four land-grant university research and extension regions. The Northeast region involves the states of Pennsylvania, Maryland, and Delaware and all states to the northeast of them. The North Central Region involves Ohio, Indiana, Illinois, Missouri, and Kansas and the states to the north of them. The Southern Region involves North Carolina, Kentucky, Arkansas and states south of them, including Oklahoma and Texas. The Western Region includes Montana, Wyoming, Colorado, New Mexico and all states to the west of them, including Alaska and Hawaii.

[4] This is a total of $6.8 million to the regions from the total SARE funding of $8.1 million for FY 1995. The remaining funds ($1.3 million) are used for administration and for information dissemination.

federal funds during this 1988–1993 period, which was matched by $30.7 million in nonfederal matching funds. Nationally, SARE and ACE projects with an experimental component and on whole farm systems received the largest share of the federal funding (55 percent), followed by whole farm demonstration and education, training, and information transfer (36 percent). Subject areas receiving the major portion of funding were communications, education, and marketing; field crops; and soil, water, nutrient, and waste management. Regional emphases varied somewhat from these national emphases, but were generally consistent. Rural quality-of-life projects received the least funding among the defined categories (29).

The content of the projects is left to the discretion of the proponents. Quite often successful proposals include economic components, as well as extension and outreach components (which are weighed heavily in the evaluations of research projects). An educational component is estimated to be part of 20–30 percent of the projects (16). Both the ACE and SARE programs successfully address the three components of sustainable agriculture (including economic viability) and incorporate research and extension into a common program. ACE and SARE have also been successful in nurturing diverse projects that represent the range of growing and farming conditions in the region (as called for in the chapter) and in ensuring that a reasonable proportion of crop and livestock projects are funded.

To further projects that relate to farmers and draw on their experience and expertise—beyond the extent to which the research and extension projects already do so—producer grants are also awarded directly to farmers for applied research and demonstration projects. The North Central region started its producer grant program in 1992, the Northeast in 1993, and the Southern and Western regions in 1994. To fund these, each regional council allocates $100,000 from its allocation for SARE projects. Proposals are reviewed by the regional councils and awarded competitively based on merit and relevancy, just as for the research and extension proposals. For example, in FY 1993, the North Central council made 31 grants, ranging from as low as $575 (for establishing hazelnut windbreaks on an Iowa farm) to as high as $5000 (for replicated manure use trials in Wisconsin, rotational grazing for custom dairy heifer feeding in Wisconsin, and grazing on former CRP [Conservation Reserve Program] acres in Minnesota).

The regional administrative councils are aided in their administration of the programs by four regional host institutions (University of Vermont, Northeast Region; University of Nebraska, North Central Region; University of Georgia, Southern Region; and Utah State University, Western Region) also authorized in the chapter. These host institutions manage the grants process, negotiate budget and contracts, and provide administrative and fiduciary oversight. They also provide for information, education, and outreach about sustainable agriculture, including newsletters, speakers, publications, and other types of electronic and printed communications.

A crucially important element of sustainable agriculture—for both SARE and ACE programs and also for sustainable agriculture as a USDA mandate and responsibility—is the extent and quality of involvement of the several USDA agencies that are relevant to and involved with sustainable agriculture. Clearly, the agencies are involved through their representatives in the regional administrative councils and on the National Advisory Council. SAES are involved because much of the project money flows through them and to their scientists. Support for the programs varies among the regions, but it appears to be steadily increasing.

Based on all the evidence, the SARE program is well administered and is meeting the needs and purposes envisioned in the chapter. The widespread and strong constituency support for SARE is graphically illustrated by the successful advocacy for continued funding through FY1995, in spite of the federal budget stringencies.

A second major provision of this chapter is the Federal-State Matching Grants Program. Funds have not been appropriated by Congress for it,

nor have funds otherwise been provided. The program does not exist, nor is there discussion or evidence that its implementation is being, or should be, contemplated. The rationale for this appears to be that the current programs (SARE and the training programs described for Chapter 3, combined with existing state programs) meet the intent of this provision.

Chapter 2: Integrated Management Systems

Notwithstanding the definitions for integrated crop systems and integrated resource management systems, and the emphasis on systems in the subtitle, this chapter has not been implemented as a part of SARE and related programs. Congress has not appropriated funds for it, nor has USDA otherwise allocated funds to it. In fact, at the beginning of FY 1994, Congress specifically stated by letter that the funds appropriated for training were to be spent for the purposes of Chapter 3, not for those of Chapter 2. Given the success of the SARE program and its coverage of both plant/crop and livestock areas, it is reasonable that this program be held in abeyance, especially if its purposes can be addressed as part of SARE, as it appears they can be. Indeed, a separate program is philosophically not consistent with the entire rationale for sustainable agriculture (which is to think *systematically*, not compartmentally). To date, a significant number of the projects funded have addressed integrated management systems, and proposals of this type are encouraged. This could be further strengthened, if necessary, by further encouragement in the call for proposals and in the instructions to the technical committees reviewing the proposals.

Chapter 3: Sustainable Agriculture Technology Development and Transfer Program

This is commonly referred to as the training program (and that name will be used in this review) because training is the principal element of the chapter, given funding to date. Funding was first provided for FY 1994 ($3.1 million). This program and the SARE program are incorporated into, and managed integrally by, USDA's Office for Sustainable Agriculture Programs.

The training program, like the research and education program (SARE), is organized and managed through the regional councils, assisted by the regional host institutions. For FY 1995, $693,000 was provided to each of the regions. The chapter established that the funds were to be allocated to proposals on a competitive basis. This has been done, using merit and relevance to training needs as the principal criteria for making the awards. Each regional council established a merit and relevancy review process for these awards of a type similar to that used for evaluating the research and extension projects. A technical review committee was specifically established for the training awards. The same approval process was used, involving the regional and national councils and, finally, approval by CSREES on behalf of USDA.

The work of the regional host institutions for the training programs warrants specific comment. These institutions are also the regional training centers specified by the chapter. Each regional host institution has a coordinator for training in the region. Functions carried out by the host institutions, and coordinator, include participation in the Sustainable Agriculture Network (a national network of more than 700 persons and groups involved in providing information about sustainable agriculture); talks and presentations; and preparation and distribution of printed publications including booklets, bulletins, and newsletters. In addition, all publications are made available in two additional, electronic forms: distribution of diskettes for use in personal computers and downloading from the Internet.

It may be expected that this program will yield good results, based on the already established and positive record of the regional councils for the SARE program. However, it is too early to determine the effectiveness of the projects (which last two and three years), because a number of them have only recently been completed.

A second program was established by the regional councils to create, first, a strategic training plan for each state and, then, an implementation plan. This involved a one-year allocation of $10,000 to each 1862 and 1890 land-grant university ($3,000 to the District of Columbia) from the total training funds. The regions continued this funding ($10,000–15,000 per land-grant institution) for a second year (FY 1995) from their regional allocations. It is too early to determine the effectiveness and value of this program.

This chapter specified that additional programs be undertaken. One of these programs, geared to providing technical guides and handbooks, has not been explicitly done. Rather, the information components of the SARE program, the information and knowledge dissemination functions of the regional host institutions, and the materials for the training program have received priority. To a significant extent, the outputs from these activities should suffice. In any event, the regional councils are in a good position to determine whether guides and handbooks should be prepared in addition to the documents already developed and prepared. Another effort, which involves the training of cooperative extension agricultural agents and is required by the chapter, is being implemented as a goal that each will be trained, but on a voluntary rather than a required basis. In a third effort, regional sustainable agricultural specialists were established in the form of sustainable agricultural training coordinators for each of the four regions, and each state extension system has identified a sustainable agriculture training coordinator.

THE PLACE OF SUSTAINABLE AGRICULTURE IN USDA'S OVERALL PROGRAM

As noted at the outset, Congress has directed that sustainable agriculture be emphasized in USDA's overall program. To date this emphasis and attention, by the relevant agencies and by the policy leadership of USDA, has been lacking. For example, the 1992 study by GAO discusses the agencies involved and the extent to which effective leadership and management have been provided. The agencies include ARS, the Cooperative State Research Service and Extension Service (now combined into CSREES), Economic Research Service (ERS), National Agricultural Library, Soil Conservation Service (now the NRCS), Animal and Plant Health Inspection Service. GAO also examined USDA's management of its sustainable agriculture programs, including the congruence and/or conflict of policy, goals, and management. It found no single entity "responsible for overseeing or coordinating the entire issue." GAO also found program management for sustainable agriculture to be fragmented and lacking "in clear and comprehensive goals for the nine agencies involved..."(31).

There has, however, been interest and emphasis by some specific programs. For example, and as already discussed in a previous chapter, the National Research Initiative Competitive Grants Program (NRICGP)—after intensive discussion with representatives of the sustainable agriculture advocacy community—has incorporated the relevancy criterion of contribution to the long-term sustainability of U.S. agriculture into its call for proposals and its commission to proposal reviewers. In addition, one of NRICGP's programmatic cross-cuts is sustainable agriculture. More than $14 million currently goes *directly* to sustainable agriculture research, with much more applying indirectly to sustainable agriculture. NRICGP is one of the few agencies where social and economic research (a key aspect of sustainable agriculture research and extension) can be specifically funded. The state agricultural research and extension systems, which are partially supported by federal funds, have a variety of programs for sustainable agriculture.

ARS is also increasing its attention to sustainable agriculture. There was a collaborative effort between the leadership of the LISA and SARE programs, and ARS and other USDA agencies, to determine to what extent research projects contributed to sustainable agriculture. Although the results may have had some interest, the process was refined to provide full utility, and its

utility in any event was substantially limited because its methodology called for categorizing projects based on the research summaries in the Current Research Information System (CRIS) documents. CRIS, however, is a source that is open to varied interpretation relative to what is actually being done in research projects.

No matter what other actions have been taken, there has not been—until now—a systematic initiative by USDA to provide the senior policy leadership and integration of effort that sustainable agriculture warrants as a major cross-cutting issue. Very recently (August 1995), an initiative was established by the Deputy Secretary to provide this leadership and integration. More than 50 persons are meeting biweekly to create action plans, which are to be completed by December 1995. Several agencies are involved, including the science and education agencies (such as CSREES, ARS, and ERS), NRCS, and other relevant agencies in USDA such as in rural development and in marketing.

Creation and action by this interagency group is an important step toward establishing sustainable agriculture as a priority program within USDA. It should help to integrate the work among the several agencies relevant to sustainable agriculture and increase collaboration and cooperation among them; provide a coherent management system for USDA's work in sustainable agriculture; and provide USDA accountability. It remains to be seen what will emerge. Optimally, it would include clear emphasis throughout USDA; a streamlined and clear USDA management and oversight structure; clear, compelling goals and objectives; a system of funding that combines USDA leadership and emphases with incentives and opportunities for scientists and extenders/appliers; a system of accountability, including clear criteria and expectations; a set of expected achievable and meaningful outcomes; measurable performance indicators; and clear roles and expectations for each of the relevant agencies, separately and also collaboratively with cognate agencies. A particularly valuable outcome would be a *unified and integrated strategic and operational plan,* which incorporates each of the relevant agencies (and state and other partners) separately and collectively.

PERSPECTIVES ON SUSTAINABLE AGRICULTURE

Clearly, sustainable agriculture is an issue of major proportions: in its inherent substantive content; its longevity as a Congressional concern and interest; and in the pervasiveness and inclusiveness of its organizational and intellectual components. Further, it is a particularly attractive meeting ground where environmental and social interests and perspectives converge with food production and agricultural productivity interests.

Just as important, sustainable agriculture is an inextricable component of sustainable development—a recent, momentum-creating international emphasis. This is particularly apt because agricultural development is the basis for social and industrial development, and sustainability of the environmental resources needed for agricultural and food production is a vital international concern.

If sustainable agriculture is a key issue—and if sustainable agriculture is embracing of much of what we can call the agriculture/food/environment research and extension system and should thus be embedded in that system—then it deserves, and should be accruing, major attention and support from USDA and the entire agricultural research and extension system. This support is still only limited, compared with what it reasonably could be. Nonetheless, it is important to point out that support is increasing.

It further follows that a leadership and management system of commitment, stature, and influence needs to be in place to guide and support development of research and extension for sustainable agriculture. This involves creating effective organizational means for bringing together the agencies (inside and outside USDA) relevant to sustainable agriculture, using their expertise, and combining them together so as to create strategic and operational approaches that

integrate their special capabilities. Leadership and commitment must be fused with strategic focus and operational plans to produce results that combine the best that can be obtained and create new direction and strength.

Irrespective of what directions may be taken in the future, a particularly important feature of the SARE program, as already pointed out, bears examination: the way in which the SARE and national training programs are organized, directed, managed, and reviewed. This feature involves combining the separate but congruent interests of knowledge users, knowledge extenders and applicators, and knowledge producers into an effective organizational framework. It involves both a "market pull" from the knowledge users based on their needs and a "market push" from the knowledge producers based on their research interests and opportunities. The organizational approach established by FACTA and implemented in the field combines researchers and extenders, farmers and agribusiness enterprises, associated governmental agencies, and involved non-governmental organizations into an effective, and enthusiastically supported research selection and management system that is results-oriented.

The agricultural research and extension system, of course, enjoyed much success by using this paradigm. Indeed, the system continues to be an especially powerful model for research, development, and application, both nationally throughout all of American society and worldwide. But the evident success of this paradigm for sustainable agriculture gives it renewed emphasis and compels the view that other major issue-oriented programs could profit from its intensified use.

Alternative Agricultural Research and Commercialization 5

Congress in FACTA gave major attention to the broad topic of new agricultural products and new uses for traditional agricultural products. This attention reflects widespread national interest in diversifying the agricultural production sector beyond traditional foods and fibers; expanding and intensifying the economic vitality of the agricultural and farm sector; and expediting technology transfer from laboratory to commercial use.

A number of FACTA provisions illustrate this interest and attention. For example, the purposes for the federal agricultural research and extension system (see chapter 2) specifically include a provision for developing "new agricultural crops and new uses for agricultural commodities" (Section 1602). The Supplemental and Alternative Crops program, designed "to develop and implement a pilot research program to develop supplemental and alternative crops," was extended through FY 1995 (Section 1601). A related FACTA provision called for "developing...commercial uses of mesquite" (Section 1672). The Critical Agriculture Materials Act, "to carry out demonstration projects to promote the development or commercialization of critical crops," was extended through FY 1995 (Section 1601). The Research on Alcohol and Industrial Hydrocarbons program was authorized through FY 1995. One of the six priority research areas in the National Research Initiative Competitive Grants Program (NRICGP), established by FACTA, deals specifically with new crops, new uses, and value-added processes. It was funded starting in FY 1992. Generically, an Agricultural Science and Technology Review Board was established (Section 1605) which will, among other things, make assessments of technology transfer initiatives and the extent to which agricultural research and extension programs foster "a diversity of products that can be marketed by the farm operator" and "develop new farm crops and enterprises that are economically and environmentally advantageous and enhance agricultural diversity." This interest by Congress is buttressed by two reports to Congress from the Office of Technology Assessment: *Agricultural Commodities as Industrial Raw Materials* and *Agricultural Research and Technology Transfer Policies for the 1990s* (25, 26).

Given this broad emphasis on new uses and products, two major initiatives were taken by Congress: (i) establishment of a program and organizational structure for Alternative Agricultural Research and Commercialization (subtitle G, sections 1657–1662) and (ii) establishment of

the Agricultural Science and Technology Review Board (section 1605). These two initiatives are the focus of this chapter

ALTERNATIVE AGRICULTURAL RESEARCH AND COMMERCIALIZATION (SUBTITLE G)

The purposes of subtitle G are to (i) "authorize research in the modification of plants and plant material...and other agricultural commodities...to develop and produce marketable products *other than* (emphasis added) food, feed, or traditional forest or fiber products"; (ii) commercialize these products to produce jobs; (iii) direct efforts "toward the production of new industrial products that can be raised by family-sized agricultural producers"; and (iv) foster "economic development in rural areas of the U.S. through the introduction" of these new products from agricultural commodities. Compared with provisions in previous farm bills, subtitle G provides substantially greater emphasis on alternative research and commercialization.

To achieve these purposes, Congress established the Alternative Agricultural Research and Commercialization Center (AARC Center). The center is to "operate as an independent entity" within USDA, and its director is to be appointed by a nine-person board, which in turn is appointed by the Secretary. The enabling legislation specifies that the director reports to the Secretary. Currently, there is a working arrangement for the director to report for organizational and administrative purposes to the Under Secretary for Rural Economic and Community Development. The board is to have one member from USDA, a scientist, a producer or processor, and persons privately engaged in commercialization. In addition, there are to be two scientists from a panel of four experts in applied research relevant to development and commercialization of non-food, non-feed products nominated by the Director of the National Science Foundation. Similarly, there are to be two persons from a panel of four who have relevant financial and management expertise nominated by the Secretary of Commerce.

The center is authorized to undertake two major functions to aid commercialization. One function is to conduct research on developing products. The other is to aid the commercialization process through product development and prototyping, marketing and economic analysis, precommercial development, early stage manufacturing and testing, and product introductions. Of these two broad functions, the center has emphasized the second in the belief that it is currently the most cost-efficient manner of expediting commercialization and increasing the center's revolving fund. The major research function is left, appropriately, with research and development agencies, either public or private. No research and development will be done until the fund is substantially larger; and even then, if such work is done, it will be distinctly different in priority and type to related work done in public sector agencies (3).

As its central financial resource, the center manages a revolving investment fund, initially provided by appropriations from Congress. The fund, which is used for making investments (usually for a five-year period which may be renewed annually) to assist the commercialization of new products, and which has been established through cooperative agreements with successful originators of technologies and products, is critically important. The center has the authority to make loans but at this time has not chosen to do so. Repayment is made through a percentage of future sales or equity in the company, such as stock. Returns to the fund are to be used to fund additional projects.

The center does not duplicate existing programs. It is designed to complement USDA's research agencies and programs, and appropriately be a bridge between research and development and the commercialization of research results. As such, it has a central role in USDA's overall program of technology development and transfer, whether the technologies are derived directly from USDA programs or not.

Taking this major step for technology and product commercialization is consistent with initiatives throughout the country that aim to bridge similar technology-commercialization gaps. The Cooperative Research and Development Agreements for federal agencies aim to do this. Similarly, universities across the nation have taken similar steps by creating research parks, establishing aggressive patenting and licensing programs, and modifying longstanding policies to be more involved and/or helpful to the commercialization process, including assisting formation of start-up companies (12,32).

USDA established the center in March 1992. Operations began soon thereafter. The board was established at the outset, and there have been changes in it since then to reflect new emphases and make operations more effective. As of June 1995, 45 projects had been selected and funded. During FY 1994–95 (the first two years of full operation), the center reports that it invested \$15.3 million, matched by \$43 million from private partners, in 39 projects. Project selection, management, and funding is presented below.

Congress in FACTA authorized funding of \$10 million for the center for FY 1990, \$20 million for FY 1991, and then \$75 million annually for FY 1995–2000. Appropriations have been far short of these authorized amounts. Total appropriated funds have been \$4.5 million (for FY 1992), \$7.25 million (FY 1993), \$9 million (FY 1994), and \$6.5 million which was rescinded to \$5 million (FY 1995). These funds have been matched, overall, in a 2–3:1 ratio by private partners, with matching on specific projects ranging from 1:1 (the minimum permissible match) to 7:1 (private:public). For example, the \$9 million appropriation for FY 1994 has been matched by \$25 million from private partners. Given the rapid start-up of the program and the staff effectiveness in selecting and managing the projects, it is clear that more funding is justified. The staff estimates that the minimum number of staff in place can handle substantially more projects. It is too early for projects already funded to know whether the investments have been successful. The results should be clear in the next year or two. At that time, decisions can be made about adhering to the original authorization schedule. Until then, it is reasonable to support the center at the \$10–20 million level per year.

No formal evaluations have yet been done by the center on rates of return for technologies in which investments have been made. It would be prudent to do this evaluation using sound accounting and financial management principles as early as possible, both to ascertain returns to the revolving fund, to assess effectiveness of the investment strategy to date, and to guide any necessary program modifications during the next two years.

Emphases of the center are on non-food, non-feed products derived mainly from plants (as noted above). Products derived from animal-based materials can be no more than 25 percent of the investments. A specific aim is to encourage the development of "bio-friendly" products.

Project selection is the key step. Rather than choosing or targeting technologies itself, the center has opened its doors to proponents of technologies and products. This is a wise approach, based on accumulating experience throughout the country, where the "push" of initiative, drive, and commitment of the inventor-entrepreneur is generally the first, key component in developing technologies and products. Without that personal commitment and capacity, technologies and products have a substantially decreased possibility of being effective.

The center solicits proposals in the usual way and also accepts those that come in over the transom. Proposals must be accompanied by a business plan. Proposals are first evaluated by outside reviewers (selected by center staff) who are knowledgeable about the proposed technology and product. If the first reviews are negative, the board does not receive the proposals. If they are positive, the board selects proposals for its own review of financial capacity and probity and for further technical evaluation. This review is done through a site visit that includes one board member and relevant technical experts from outside the board and center staff. Of the projects evaluated, about 10 percent are selected for fund-

ing. The quality of proposals, however, are such that center staff estimates 35–40 percent warrant funding using existing criteria.

There is no requirement for geographic distribution of the investments. However, it is center policy that the location be "blind" to the extent possible in initial evaluations. Currently there are projects throughout the country, including Pennsylvania, Texas, California, Florida, Michigan, Arizona, and the grain belt. By definition, all projects must be in rural areas. There is no requirement as to size and stage of development of firms. Current projects are concentrated in firms that range from early start-ups to medium-size enterprises. One project has been with a large manufacturing company, and it was done in the first year of the center's operation.

After reviews are completed and the board gives final approval, contractual relationships are established between the center and the applicant. Among other considerations, terms of repayment and any equity interest to be retained by the center are established.

Funding is provided through repayable investments. Generally the amount is in the $250,000–$300,000 range. One million dollars is the maximum any project should receive. As noted, although the minimum private sector match is to be 1:1 (private:public), it has ranged to date from 1:1 to 7:1. Of the appropriations from Congress, not more than 15 percent can be for administrative services, and not less than 85 percent is to be for the revolving fund.

Projects funded in FY 1993 include the following representative examples: ethanol as a replacement for methanol in windshield washer fluid; ethanol from woody plant materials; a new material for furniture and decorative ware from waste newspaper and soybean meal; biodiesel fuel from soybean oil; biodegradable polymers from wheat; biodegradable kenaf mats for application of grass seed and nutrients; wool waste as material for cleaning up oil spills; kenaf paper; wood strands flaked from pulpwood timber molded into furniture parts; conversion of kenaf into paneling; oil from the new crop Lesquerella as a basis for lubricants and cosmetics; and blending of *Bacillus thuringiensis* with biodegradable carriers to provide environmentally friendly pesticides. Projects funded in FY 1994 include: building panels from straw; bacteria endemic in cotton cellulosic waste that degrades oil; mesquite briquettes as a substitute for coal briquettes; utility poles made using a plywood-like core and skin technique; crambe oil for personal care products and surfactants; wheat straw and recycled plastic to form composite sign posts; potting soil made from tree and yard trimmings combined with animal manure and inoculated with plant disease-combating microorganisms; and, similarly, compost from agriculture and forestry wastes as a carrier for bacterial biocontrol agents (3).

FACTA provides for regional centers. These were not established initially because of the start-up of the center and the limited funds. Collaboration has recently been established with two Midwest centers—the Agricultural Utilization Research Institute (Crookston, MN) and the Kansas Value-Added Center—which were selected through a competitive process. Initial agreements were established in summer 1995. Under the current agreements, the major purposes of these regional centers are to assist in review and evaluation of proposed technologies; to establish a database and clearinghouse for new uses; and to provide strategic investment information to the board on the potential for business opportunities for new uses and products. They are not, however, functioning in the full regional center role as envisioned in the enabling legislation.

Overall, implementation of the AARC Center is proceeding satisfactorily. Prudent decisions regarding mechanisms for project review and selection have been made. Sound investment policies are in place, both as to the private-public match ratios and the form of repayments expected. The portfolio of technologies and their widespread geographic distribution is appropriate. It is too early to determine the success of the investments. However, it is useful to note that two companies are already making payments to the center based on the signed agreements, and a

third will begin repayments as of January 1, 1996 (3).

AGRICULTURAL SCIENCE AND TECHNOLOGY REVIEW BOARD (SECTION 1605)

The Agricultural Science and Technology Review Board was established in FACTA (section 1605) for the purpose of providing "technical assessment of agriculture science issues and...[considering]...the impact of technologies on agriculture and the social and economic well-being of communities." It is designed to advise the Joint Council on Food and Agricultural Sciences and the National Agricultural Research and Extension Users Advisory Board. In addition, it is to provide assessment of "public and private agricultural research and technology transfer initiatives..."

The board was established by the Secretary in 1992 and has had five meetings to date, including a public forum early in 1995 to review its proposed technology assessment protocol (24). In accordance with Congressional requirements, the majority of the 11 board members are from the private sector and represent technology assessment, technology transfer, the agricultural and environmental sciences, and international programs. The board gave its first report (for 1994) to the Secretary in 1995. Appointments to the board are made by the Secretary through the Joint Council on Food and Agricultural Sciences, which provides the board with some staff support. Current budget constraints have, however, meant little personnel support for the board. If there is not more personnel support, it is difficult to believe that the board can make much of a contribution. Compounding this problem is the fact that the board maintains minimal or no relations with other entities in USDA. This is to be expected, given the early stages of development of the board's program, but changes must be made in the future.

A fundamental issue is the optimum location within USDA for technology assessment. At least five different approaches can be considered: (i) make technology review and assessment everyone's responsibility, and institutionalize it as such throughout USDA; (ii) create a separate board outside the operational components of USDA, such as the Technology Review Board; (iii) incorporate technology assessment directly into the Joint Council on Food and Agricultural Sciences, rather than have the board a companion entity to the council; (iv) provide strong institutional support for the board, or an equivalent entity at the Secretary level, and give it enough staffing to do its work in respectful relationship with the operating agencies; (v) create technology review and assessment functions within each of the operating agencies (such as ARS, FS, and CSREES) to assist with these functions *and* create a coordinating mechanism that ensures commitment and collaboration throughout USDA.

Clearly, technology assessment and review are major interests. Consequently, it is reasonable to focus on approaches (i), (iv), and (v) because they are "closer to where the action is." Approaches involving the current board (ii) or a variant of it (iii) seem less appropriate because they are separated from the agencies, even though the current board has a broader mandate than simply providing advice to the Joint Council. Whatever is considered, approach (i)—institutionalizing the mandate, importance, and responsibility for technology assessment, review, and transfer throughout USDA—should at a minimum be taken. Approach (v)—creating technology assessment and review functions—is also appropriate. It is substantially more problematic, however, because so much of CSREES' work is done through the state and land-grant partners. By virtue in the 1980s of federal legislation and subsequent USDA action, the primary technology review and assessment function for these partners rests with them, not with USDA. Given the emphasis on technology review, assessment, and transfer at the state and university levels, this should not be a problem.

Financing, Organizing, and Managing the Agricultural Research Portfolio[1] 6

Agricultural productivity has increased rapidly in the United States—more rapidly than productivity in the general economy. Many attribute a good portion of this growth to public-sector agricultural research which is conducted primarily through land-grant colleges and USDA research agencies. In recent years, the agricultural sciences have increasingly been asked to do more with less. Questions have been raised about whether the old research institutions are still needed, and about how they should adapt to accommodate changes in science, in scientific institutions, in society and social attitudes, in government, in agriculture itself, and in the general economy.

The post-war years have been characterized by a general growth in congressional interest in agricultural research, and political involvement in allocating research resources. Funds earmarked for particular purposes, or to be spent in particular locations, have increased markedly, while other types of funds have increased at a slower rate or declined. Recently, as a reflection of concerns about the size of the government budget, research investments have been scrutinized more carefully and demands for accountability have intensified.

In the discussions leading up to the 1995 farm bill, agricultural science policy has been put, along with other agricultural policies, on the negotiating table. Given recent moves toward freer global trade, competitiveness has assumed ever greater importance. And as components of competitiveness, environmentally supportable improvements in agricultural productivity, and in product safety and quality, driven by research, are critical. There is not yet a clear consensus on what role government should play, but there is no doubt that it will be involved in some way.

The purpose of this chapter is to provide a basis for policymakers to approach agricultural research policy questions—questions concerning the financing, organization, and management of public-sector agricultural research programs, including accountability provisions—in an objective and consistent fashion. The chapter reviews the U.S. government's agricultural research policies and related arrangements for administration and accountability. It draws on relevant economic principles to review and evaluate the past and present policies as a basis for considering policy directions for the future.

[1] Material in this chapter was drawn from the OTA contractor report, "Agricultural Research in the Public Interest," by Julian M. Alston and Philip G. Pardey, May 1995.

The primary focus of the chapter is on how public sector research can compensate for the private sector's relative lack of investment in agricultural research. Discussion is not restricted to whether the total amount of taxpayer funding is adequate. To achieve the greatest gains for society as a whole, a more fundamental rethinking of the basis for and approaches toward *financing*, *organizing*, and *managing* public-sector agricultural research is needed. Most previous commentators have, simplistically, called for more federal research dollars. Other public policy mechanisms can and should be used, along with taxpayer funds, to increase total private and public investment in agricultural research, and to promote a socially profitable mixture of research programs (from basic to applied research; across disciplinary areas; across commodity-oriented research programs; in terms of geographic relevance; among environmental and other natural resource issues). The policy analysis must include a consideration of different funding mechanisms—show how they affect the cost of research (including who bears the cost in relation to who benefits), and how they affect incentives for private research.

The benefits that public and private research provide to society are also affected by existing mechanisms for allocating public sector research resources, and for managing those resources to ensure that they are used to greatest effect. Since, ultimately, individual scientists make many of the critical decisions, the relevant issues extend beyond simply allocating resources to high-priority questions. Mechanisms to ensure that individual incentives are compatible with the public purpose, and some accountability arrangements, are also desirable. Such considerations lead to a questioning of the use of political criteria versus formula funding or competitive grants to allocate research resources—at least about how the decisions concerning those funding arrangements are made.

A rethinking of options extends beyond the boundaries implied by the current institutional structure (which is dominated by the State Agricultural Experiment Stations, or SAES, and the USDA intramural laboratories) to consider a greater use of in-between alternatives, such as regional research institutions, and to allow open competition among these different institutions, where appropriate, for available funds.

The economic rationale for government intervention in agricultural research is market failure—in this case, a socially undesirable situation that the free market will not correct on its own. This leads, logically, to the use of economic arguments to determine how government can best correct the market failure. The particular virtue of the economic approach is that it provides a coherent, consistent basis for developing, considering, and evaluating alternative approaches towards financing, organizing, and managing public-sector agricultural research.

Along with the use of economics, there has to be an integrated, rather than piecemeal, assessment of the full range of public policy issues related to agricultural research. Decisions must be made concerning the amount of resources (federal, state government, and other) to allocate to research, the way research is funded, the types of research undertaken, the institutional structures related to allocating resources and conducting research, and the mechanisms for communicating the research results. All of these factors are mutually dependent and should be thought through together. Linkages among these aspects are important. Making changes in one element (for instance, increasing or decreasing federal support for research) without thinking through the implications for other elements of the system (for instance, incentives and institutional mechanisms for industry-based research support) could have undesirable and unforeseen consequences.

BASIS FOR GOVERNMENT INTERVENTION IN RESEARCH

Principles for Government Intervention

Spillovers and Externalities

A basic tenet of economics is that the benefits society receives from production and consump-

tion (in this case agricultural production and consumer consumption) will be maximized when the costs to society of that production or consumption are equal to the social benefits it provides. A "market failure" exists when private incentives lead to a different resource allocation, and a different product mix, than the socially optimal outcome. This will happen if private benefits and costs differ from social benefits and costs, so that private interests and national interests do not exactly coincide. For the purposes of this discussion, a market failure can be viewed as a socially undesirable situation that the free market will not correct on its own.

Market failures can be caused by externalities. Externalities, which can be positive or negative, result when the effects of certain production or consumption activities "spill over" to other parts of society. Groundwater that is polluted by agricultural chemicals is an example of a *negative* externality. Free-riding by others on an individual's research results is a *positive* externality.

Appropriability and Private Sector Underinvestment

Market failure in agricultural research seems to be widely taken for granted: left to its own devices, the private sector would invest too little in agricultural research. Some incentive problems arise from the economics of the research enterprise as it relates to the size of farm firms. The nature of research activity, which is usually long-term, large-scale, and risky, means that the typical firm in agriculture is not able to carry out effective research (although it can help to fund it), and institutions may have to be set up on a collective basis.[2] The main reason for private-sector underinvestment in research, however, is inappropriability of research benefits: that is, the firm responsible for developing a technology may not be able to appropriate all of the benefits accruing to the innovation. The reason for such an "appropriability" problem is often that fully effective patenting or secrecy is not possible, or that some research benefits (or costs) accrue to people other than those who use the results.[3]

Appropriability problems give rise to an asymmetry between the incidence of benefits and the costs of research. For certain types of research, the rights to the results are fully and effectively protected by patents, so that the inventor, by using the results from the research or selling the rights to use them, can appropriate the benefits.[4] Often, however, those who invest in research cannot capture all of the benefits—others can "free-ride" on an investment in research, using the results and sharing in the benefits without sharing in the costs.[5] Hence, private benefits to an investor (or group of investors) are less than the social benefits of the investment and, as a result, some socially profitable investment opportunities remain unexploited. In the absence of government intervention, the investment in agricultural research is likely to be too little.

These conventional reasons for private-sector "underinvestment" in agricultural research explain the major result from the empirical literature concerning different commodities and different countries: agricultural research has been, on average, a highly profitable investment from society's point of view. In turn, this suggests that research has been underfunded, and that current government intervention may be inadequate. This is not to say that the amount of government spending necessarily should increase. Changes in

[2] There are exceptions to the *typical* situation, but even when firms are large enough to find it profitable to carry out some research, there is still likely to be too little research for the other reasons (appropriability and externalities).

[3] This appropriability problem extends beyond relations among single individuals to relations among collectives, such as one producer cooperative or industry group versus another, and among states and even countries.

[4] For instance, the benefits from most mechanical inventions and developing new hybrid plant varieties, such as hybrid corn, are mostly appropriable.

[5] For instance, an agronomist or farmer who developed an improved wheat variety would have difficulty appropriating the benefits: the inventor could not get the potential social benefits simply by using the new variety himself; but if he sold the (fertile) seed in one year, the buyers could keep some of the grain produced from that seed to use as seed thereafter.

government intervention can take many forms. Some see it only in terms of increased government (that is, taxpayer) funding of research, but that is only a part of the problem. The federal government can also act to change the incentives for the private sector or state governments to increase their investments in private or public research. That government intervention is inadequate implies simply that the nature of the intervention should change so as to bring forth either more private investment or more public investment. In addition to efficiency gains from increasing the total research investment, the government can also intervene with a view to improving the efficiency with which those resources are used within the research system.

Environmental Externalities

Spillovers and externalities may be relevant not only in relation to the products from research, but also through problems in the markets for agricultural outputs and inputs, leading to indirect problems in research. Agriculture often involves environmental externalities arising from spillover effects of agricultural production on other agricultural producers (for example, through effects on incidence of pests) or others through impacts on groundwater or air pollution that are not compensated through markets. Even in the absence of market failures associated with the atomistic nature of agricultural production, and appropriability, there will be problems with incentives, so that the direction of research will be biased against technologies that help alleviate the effects of environmental externalities and in favor of technologies that make the effects of environmental externalities worse. In the absence of government intervention, commercial decisions will tend to produce too much pollution and preserve too little pristine wilderness.

Agricultural research can generate technologies that are environmentally friendly, relative to the current technology; but it is not sufficient to invent the technology. The very nature of (negative) externalities is that it doesn't pay private investors to make an effort to reduce them, either in the choice of production practices with given technology, or in the choice of the direction for technology to evolve through research, development, and adoption decisions. If agricultural research is to be effective in reducing environmental externalities, the resulting new technologies must be adopted, and if they are to be adopted, they must be viewed as privately profitable. This could happen in one of two ways: either a new (environmentally friendly) technology is privately more profitable than the current technology, under the current incentives, or the government acts to change the adoption incentives as well. Similar arguments apply to the development and adoption of technologies that consume stocks of unpriced or underpriced natural resources. Private incentives are liable to lead in the direction of developing and adopting technologies that consume too many natural resources, unless government acts to modify the incentives and "internalize" the externalities.

Research Beyond the Farm Gate

The farm input suppliers, and other components of the agribusiness industry that transport, processes, and markets farm products, tend to be relatively large firms, large enough to exploit economies of size in research. The technologies they use tend to be mechanical, of a type that can be protected by patents, or process innovations that can be protected by secrecy. The technology used by agribusiness is often not specialized to agribusiness, and can be adapted from broader industry (for example, refrigeration or transportation technology). For these reasons, appropriability problems tend to be less important in the agribusiness industry than in the farming industry. Thus, the potential role for the government (by inference, the chance of market failure) is *generally* greater in research pertaining to farming than in research pertaining to agribusiness.

There are exceptions, however. Some parts of the farming industry are involved in vertically integrated structures where research benefits can be internalized (for instance, the broiler chicken industry); certain types of technology applicable to farming are effectively protected by patents (for instance, machinery, hybrid lines of plant

varieties). Research incentive problems are important in some parts of agribusiness. In plant breeding, for example, there is "natural" appropriability for hybrid lines, since the crop does not reproduce itself, but for open-pollinated varieties it is necessary to legislate and enforce property rights to ensure appropriability.

It is important to exercise discretion in judging specifically where the market failures in research are important and where they are not, since government investment in research in a particular area is likely to crowd out some private-sector research. In cases where private-sector underinvestment in research is not otherwise a problem, public-sector research can *cause* a private-sector underinvestment.

Rates of Return to Research

The payoff to research can be summarized in terms of the private rate of return (comparing private costs and benefits to the investors in the research) and the social rate of return (comparing benefits and costs to society as a whole). Alston and Pardey (1) have documented the results of a large number of studies of social and private rates of return to agricultural research. The overwhelming conclusion from that collection of results is that estimated rates of return to agricultural research have been very high, typically well in excess of 20 percent per year. The relevant comparison is with the rate at which the government borrows money, typically 3–5 percent per year. Since the rate of return to research is much greater than the borrowing rate, there appears, in general, to have been a gross underinvestment in agricultural research.

It is less clear from this type of evidence whether there has been an underinvestment in agricultural research relative to other industrial research. For instance, a number of studies that were recently documented by the Industry Commission (IC) (13) in Australia showed rates of return to industrial research that are comparable to rates of return to agricultural research: typically well in excess of 20 percent, and often ranging around 100 percent per year.[6] Hence, the rate of return evidence does not support a diversion of resources from industrial research to agricultural research. Rather, taken at face value, the evidence on rates of return to both the industrial research and agricultural research supports the view that resources should be diverted from other economic activities to both.[7]

Some reservations can be raised about the evidence on rates of return. Most of those studies have not adjusted for the effects of price-distorting policies (such as commodity price support programs) on the measures of research benefits, an omission that might lead to over- or understatement of the benefits and the rate of return (2). Most have not adjusted for the effects of the excess burden of taxation on the measures of costs, an omission that will lead to a systematic understatement of the social costs and an overstatement of the social rate of return (9).

On the other hand, a number of factors could lead to *underestimated* rates of return to agricultural research, including the omission of spillovers from agricultural research into nonagricultural applications and the consequences of such things as environmental, food safety, and social science research that are not reflected in conventional productivity or rate-of-return measures. Allowing for all these potential sources of error, on balance it seems likely that the rates of return to both public and private agri-

[6] The IC documented 20 rates of return to industrial R&D (reported in 10 studies of the United States and 4 studies of Japan) to the industry and, where available, to firms in other industries as well as to the nation as a whole. The unweighted means of the annual rates of return were 26 percent to the industry (standard deviation of 13 percent), 75 percent to firms in other industries (standard deviation of 27 percent), and 85 percent to the nation (standard deviation of 22 percent). The IC also reported similar evidence on rates of return to industrial R&D in Belgium, Canada, France, Germany, and the United Kingdom.

[7] The rates of return may not be fully comparable between agricultural and industrial R&D (or even within those classes), since different studies make different types of assumptions, use different concepts, and hold different things constant. Such details can have substantial effects on the estimates and thus are important for making relevant or meaningful comparisons.

cultural research have been high and that there has been underinvestment.

Forms of Government Intervention

It is one thing to establish a case of market failure. It is another to determine the best action for the government to take to reduce the costs that society must pay for the market failure. Indeed, taking *no* action may be the optimal policy. Many interventions are used in relation to agricultural research. They include improvements in private property rights (such as recent changes in intellectual property rights involving plant variety protection or "utility patents" for plants), enhanced incentives for private research (through the provision of tax breaks, direct subsidies, or other incentives, for instance), the provision of public funds for publicly or privately executed research through competitive grants, or the creation of new public or private sector research institutions (as an example, legal arrangements under which an industry funds research cooperatively). Another way to finance public sector agricultural research is to sell the scientific results (even public sector organizations such as universities now often patent their research results whenever possible, and sell the product).

These alternatives may all differ in terms of their incentive effects and the total cost to society of financing research. An intervention is justified only if it improves the situation by reducing social costs of market failure—the benefits of the intervention must be greater than the costs. Different interventions will be more or less effective at correcting different types of market failures; they will also have different distributional (or equity) consequences.

The dominant U.S. strategy has been to use state and federal government revenues to finance public or private sector research. This includes the provision of tax breaks and other financial incentives for private research, which involves a loss of government revenues, as well as the direct use of government funds both to finance private research, through grants and contracts, and to finance the production of knowledge in a variety of publicly administered research organizations.

Public Sector Research Expenditures

Public sector research in the United States is big business by most measures. In 1994 the federal government spent a little more than $64 billion on research, compared with only $178 million in 1949.[8] About $38.8 billion, or 57.1 percent, was spent on defense-related research and development, down from its 69.7 percent share of total research spending in 1987. In 1994, about $29.1 billion was earmarked for nondefense research and development, of which federally funded agricultural research accounted for just $1,142 million, or 1.7 percent of the total. Table 6-1 gives a more detailed, longer-run perspective on agricultural research spending in the United States. In 1889, shortly after the Hatch Act was passed, federal and state spending totaled $859.3 million. A century later the public sector agricultural research enterprise had grown to more than $2.6 billion, an annual rate of growth of 8.0 percent in nominal terms. The national system in 1889 was dominated by intramural research by USDA. By 1993 SAES accounted for 74 percent of total public spending on agricultural research, with federal laboratories operated by USDA making up almost all of the remaining 26 percent.

The sources of funds for SAES research have also changed markedly. During their early formative years, SAES received a relatively small but growing share of their funds from state sources. The proportion of funds received from state sources peaked at 69 percent in 1970 and has fallen steadily since to average only 48 percent in 1993. Funding from miscellaneous fees and sales (including funds from grants and industry checkoffs) has grown steadily as a share of

[8] These are in term of nominal or current purchasing power (i.e., undeflated figures) rather than real or constant purchasing power (i.e., which would be obtained by using a price index to deflate the nominal figures).

	SAESs[a]					
Year or decade average	State	Federal	Miscellaneous fees & sales	Total	USDA[b]	U.S. total
			(millions of current dollars)			
1889	0.08	0.59	0.06	0.72	0.14	0.86
1890–99	0.22	0.70	0.11	1.04	0.21	1.25
1900–09	0.65	0.87	0.31	1.84	1.04	2.88
1910–19	2.24	1.43	1.09	4.76	4.48	9.24
1920–29	6.01	2.11	2.09	10.21	18.44	28.65
1930–39	8.25	4.88	2.60	15.72	30.68	46.40
1940–49	15.81	7.42	5.44	28.67	40.97	69.64
1950–59	56.17	19.10	14.27	89.55	46.08	135.63
1960–69	132.10	42.87	25.20	200.18	109.32	309.50
1970–79	289.13	131.14	63.41	483.68	258.58	742.26
1980–89	646.44	359.41	207.04	1,212.89	500.37	1,713.25
1990	927.15	500.86	338.07	1,766.07	614.08	2,380.15
1991	961.73	532.15	358.72	1,852.59	650.62	2,503.22
1992	956.29	582.06	376.52	1,914.87	689.97	2,604.84
1993	960.41	632.39	387.54	1,980.33	692.29	2,672.63
			Annual growth rates (%)			
1889–93	9.52	6.95	8.93	7.96	8.50	8.04
1980–89	7.87	6.87	9.57	7.86	5.06	7.04
1990–93	1.18	8.08	4.66	3.89	4.08	3.94

SOURCE: Office of Technology Assessment, 1995. Compiled from various USDA sources, including U.S. Department of Agriculture *Inventory of Agricultural Research* data for years after 1980.

[a] Data includes experiment stations and cooperating institutions for U.S. contiguous states.

[b] Series approximates intramural research by USDA and consists of total appropriations to the Agricultural Research Service, the Economic Research Service, and the Agricultural Cooperative Service less appropriations to contracts, grants, and cooperative agreements with the SAESs made by these USDA agencies.

the total since the early 1970s and now accounts for nearly 20 percent of SAES funds.

Between 1972 and 1993, total support for SAES grew by 8.5 percent per year in nominal, or current purchasing power, terms (as shown in table 6-2) and only 2.8 percent in real or constant purchasing power terms. About 51 percent of the federally sourced resources have come from Cooperative State Research, Education, and Extension Service (CSREES) administered funds, which include funds dispersed on a formula basis, some earmarked funds, and funds made available to the states as part of the competitive grants program.[9] The remainder (about 49 percent) of the federal funds going to the states comes from other earmarked funds, funds

[9] In October 1994, USDA initiated a major reorganization which, among other changes, merged Cooperative State Research Service and the Cooperative Extension Service into a newly created Cooperative State Research, Education, and Extension Service (CSREES). This action draws the cooperative extension and research functions together into a single agency for the first time in USDA history.

[illegible]

	Federal				Non-Federal					
Year	CSREES admin[a]	USDA[b]	Other[c]	Total	State	Sales	Industry[d]	Other	Total	Grand total
	(millions of current dollars)									
1972	71.5	7.0	28.2	106.7	205.5	23.2	16.6	11.0	256.3	363.0
1973	78.2	7.7	29.6	115.4	222.1	28.1	17.7	11.7	279.6	395.1
1974	83.2	8.8	32.0	124.0	247.5	32.4	21.0	12.2	313.0	437.0
1975	92.0	11.1	35.3	138.4	284.7	37.3	24.0	15.0	361.1	499.4
1976	104.8	10.5	40.8	156.1	309.7	30.7	28.3	16.4	385.2	541.3
1976[e]	26.2	2.6	10.2	39.0	77.4	7.7	7.1	4.1	96.3	135.3
1977	118.9	12.6	55.6	187.0	321.2	39.1	32.7	21.9	414.8	601.8
1978	134.5	16.5	57.9	208.8	374.9	40.1	34.7	22.4	472.1	680.9
1979	156.3	21.1	64.6	242.1	413.5	46.7	37.1	27.2	524.6	766.6
1980	162.8	27.5	71.6	261.9	456.4	55.9	48.4	30.5	591.3	853.1
1981	174.3	33.3	83.0	290.6	501.2	59.1	53.5	38.2	652.1	942.7
1982	199.2	36.2	107.6	343.0	545.2	62.5	61.3	45.5	714.6	1057.6
1983	204.9	38.9	95.2	339.0	576.5	65.4	66.7	49.1	757.7	1096.7
1984	210.5	38.5	103.2	352.3	621.8	66.3	71.0	54.4	813.5	1165.7
1985	221.0	35.9	112.4	369.4	678.3	70.5	79.1	61.5	889.3	1258.7
1986	222.7	35.8	140.6	399.1	741.7	69.4	85.1	70.2	966.5	1365.6
1987	230.8	36.8	148.1	415.7	778.9	75.4	93.8	85.1	1033.1	1448.8
1988	247.8	42.2	153.5	443.5	823.4	84.8	99.1	91.1	1098.3	1541.8
1989	261.0	48.9	169.7	479.6	894.4	92.4	111.3	102.1	1200.2	1679.8
1990	272.8	54.1	188.6	515.5	950.1	102.4	126.6	112.4	1291.5	1807.0
1991	290.8	57.8	199.4	548.0	985.9	113.6	134.0	114.9	1348.4	1896.3
1992	316.6	60.7	221.3	598.7	981.5	116.1	143.4	121.0	1362.1	1960.7
1993	331.0	68.6	249.0	648.5	985.4	110.0	146.1	134.8	1376.3	2024.8
	Annual Growth Rates (%)									
1972–93	7.6	11.5	10.9	9.0	7.7	7.7	10.9	12.7	8.3	8.5
1989–93	6.1	8.8	10.1	7.8	2.5	4.5	7.0	7.2	3.5	4.8

SOURCE: Office of Technology Assessment, 1995. Compiled from U.S. Department of Agriculture, *Inventory of Agricultural Research,* various annual issues, table IV-E.

NOTE: Includes all state agricultural experiment stations, forestry schools, 1890/Tuskegee institutions, veterinary schools, and other cooperating institutions.

[a] Includes formula funds, special grants, and competitive grants.

[b] Includes monies received from USDA grants, contracts, and cooperative agreements.

[c] Includes contract, grant, etc., monies received from agencies such as the National Science Foundation, Energy Research and Development Administration, Department of Defense, National Institutes of Health, Public Health Service, National Aeronautics and Space Administration, Tennessee Valley Authority, and so on.

[d] Includes monies received through industry grants and agreements.

[e] Includes appropriations for the transition quarter which covers the period from July 1, 1976 to September 30, 1976.

derived from USDA grants, contracts, and cooperative agreements, funding received from agencies such as the National Science Foundation, the National Institutes of Health, the Department of Defense, and so on. These have accounted for a rising share of the SAES total, well up from their 33 percent share of federal funds just two decades ago.[10] Revenues from the sale of services and products (including royalties from patents) account for only 5.4 percent of total funds. Industry funds from grants, checkoffs, and the like still account for only 7.2 percent of the total, although this was one of the faster-growing components of funds received over the past two decades.

The differential growth rates imply a changing mixture of sources of funds, with a rising share of funds from industry sources and, of the government funds, a shrinking share of funds from state governments. Of the federal funding, competitive grants have been rising relatively quickly and have grown, along with earmarked funds, partly at the expense of formula funding. Some of these changes are in directions that should enhance economic efficiency, such as more industry funding, increased competitive grants and less formula funding—but the rate of change may be too slow, and competitive grants may still have too small a share. Other trends, such as declining state government support and the rise of earmarked funds, will not enhance economic efficiency in agricultural research.

USDA both disperses and relies on federal research funds. Table 6-3 details the deployment of federal appropriations to USDA. Since 1970 an increasing share of USDA resources earmarked for research and education has gone to research, with a corresponding contraction in the share going to education and extension services. Such services now account for a quarter of total funds, whereas in 1970 they took one-third of the available resources. ARS accounts for about one-third of all USDA expenditures on research and education, a share that has remained fairly constant over recent years. Slightly more than one-fifth of USDA expenditures on research and education are administered by CSREES, mostly earmarked to go to SAES and other cooperating institutions, although some of the competitive grant funds that CSREES oversees are spent by agencies within USDA.

Private Sector Research Expenditures

The private sector committed $3.3 billion to in-house agricultural research in 1992, about 27 percent more than the amount spent on agricultural research conducted by the public sector (table 6-4).[11] The amount of privately conducted research increased nearly 19 fold in the past three decades, a substantially faster rate of growth than occurred in the public sector. As a result, for every dollar of publicly conducted research in 1992, the private sector spent $1.27, compared with just 94 cents in the early 1960s. But, like the public sector, the growth in private spending on agricultural research slowed considerably in recent years. From a rate of growth in real spending on private agricultural research in excess of 4.5 percent per year throughout the 1960s and 1970s, the rate dropped to only 1.7 percent for the post-1980 period. The focus of this private research also changed considerably. In 1960, agricultural machinery and postharvest and food-processing research accounted for more than 88 percent of total private agricultural research. By 1992 these areas of research collectively accounted for only 44 percent of the total, with

[10] As a share of the total, not just federal, funds going to SAES, these sources of funds collectively accounted for 9.7 percent of the total in 1972 and 15.7 percent in 1993.

[11] The private R&D estimates are documented in detail by Alston and Pardey (1). They explain that measuring privately conducted agricultural R&D in ways that can be meaningfully compared with the public sector figures is problematic. Invariably, changes and inconsistencies are found in the underlying survey methods used to compile the private sector series. Also, it is often difficult to distinguish in-house R&D from other activities such as product promotion, or to distinguish agriculture-related R&D from other types of R&D, and the public and private series currently available are not always strictly comparable in terms of their coverages regarding the pre-, on-, and post-farm research orientation.

	CSREES Administered					Economics & Statistics					Education			
Year	Competitive	Others	Total CSREES	Agricultural research service	Forest service	Economic research service	Statistical service	Total	Total research	National ag. library	Extension service	Other	Total	Total research & education
						(millions of current dollars)								
1970	—	62.7	62.7	160.1	45.6	—	—	17.0	285.4	—	146.2	4.8	151.0	436.4
1971	—	69.6	69.6	178.6	48.8	—	—	18.4	315.4	—	165.6	5.5	171.1	486.5
1972	—	83.0	83.0	191.7	54.4	—	—	18.8	347.9	—	182.2	6.1	188.3	536.2
1973	—	91.5	91.5	208.1	57.8	—	—	20.6	378.0	—	197.9	6.5	204.4	582.4
1974	—	90.1	90.1	205.0	64.7	—	—	22.0	381.8	—	206.7	6.8	213.5	595.3
1975	—	101.8	101.8	224.4	77.6	—	—	24.9	428.7	—	217.2	7.9	225.1	653.8
1976	—	114.5	114.5	282.8	82.3	—	—	28.9	508.0	—	230.2	8.3	238.5	746.5
1976[a]	—	28.6	28.6	64.4	22.3	—	—	7.4	122.4	—	56.0	2.1	58.1	180.5
1977	—	129.0	129.0	282.9	89.8	24.5	4.7	29.2	530.9	—	232.7	9.2	241.9	772.8
1978	15.0	142.9	157.9	313.9	90.6	26.0	5.0	31.0	593.4	6.6	257.5	20.8	284.9	878.3
1979	15.0	159.3	174.3	328.0	95.0	28.2	5.4	33.6	630.9	7.0	263.8	21.2	292.0	922.9
1980	15.5	170.4	185.9	358.0	95.9	26.1	5.0	31.1	670.9	7.3	274.0	21.5	302.8	973.7
1981	16.0	184.7	200.7	404.1	108.4	39.5	7.5	47.0	760.2	8.2	292.2	22.4	322.8	1,083.0
1982	16.3	204.3	220.6	423.2	112.1	39.4	7.0	46.4	802.3	8.2	315.7	11.0	334.9	1,137.2
1983	17.0	215.3	232.3	451.9	107.7	38.8	7.6	46.4	838.3	9.1	328.6	11.9	349.6	1,187.9
1984	17.0	220.7	237.7	471.1	108.7	44.3	8.2	52.5	870.0	10.4	334.3	18.2	362.9	1,232.9
1985	46.0	230.6	276.6	491.0	113.8	46.6	8.4	55.0	936.4	11.5	341.2	21.3	374.0	1,310.4
1986	42.3	227.3	269.6	483.2	113.6	44.1	8.0	52.1	918.5	10.8	328.0	18.4	357.2	1,275.7
1987	40.7	253.0	293.7	511.4	126.7	44.9	3.4	48.3	980.1	11.1	339.0	18.7	368.8	1,348.9
1988	42.4	260.7	303.1	544.1	132.5	48.3	3.6	51.9	1,031.6	12.2	358.0	19.8	390.0	1,421.6
1989	39.7	270.9	310.6	569.4	138.3	49.6	2.9	52.5	1,070.8	14.3	361.4	21.9	397.6	1,468.4
1990	38.6	288.0	326.6	593.3	150.9	51.0	2.8	53.8	1,124.6	14.7	369.3	28.6	412.6	1,537.2
1991	73.0	300.3	373.3	631.0	167.6	54.4	3.2	57.6	1,229.5	16.8	398.5	34.8	450.1	1,679.6
1992	97.5	316.9	414.4	670.6	180.5	59.0	3.6	62.6	1,328.1	17.8	419.3	35.8	472.9	1,801.0
1993	97.5	317.5	415.0	671.7	182.7	58.9	3.9	62.8	1,332.2	17.7	428.4	35.7	481.8	1,814.0
1994	103.1	325.2	437.3	679.2	193.1	55.2	3.5	58.7	1,359.3	18.2	434.6	37.5	490.3	1,849.6
1995[b]	130.0	272.1	402.1	712.7	204.0	53.7	3.5	57.2	1,376.0	19.6	432.4	38.9	490.9	1,866.9

	CSREES Administered					Economics & Statistics					Education			
Year	Competitive	Others	Total CSREES	Agricultural research service	Forest service	Economic research service	Statistical service	Total	Total research	National ag. library	Extension service	Other	Total	Total research & education
						Annual growth rates (%)								
1970–80	1.7[c]	10.5	11.5	8.4	7.7	2.1[d]	2.3[d]	6.2	9.0	5.2[c]	6.5	16.1	6.9	8.3
1980–90	9.6	5.4	5.8	5.2	4.6	6.9	-5.6	5.6	5.3	7.3	3.0	2.9	3.0	4.7
1970–94	13.4	7.1	8.4	6.2	6.2	4.9	-1.7	5.3	6.8	6.5	4.6	8.9	4.8	6.2

SOURCE: Compiled from various USDA sources, including U.S. Department of Agriculture, *Inventory of Agricultural Research*, various annual issues.

[a] Includes appropriations for the transition quarter which covers the period from July 1, 1976 to September 30, 1976.

[b] Estimate only.

[c] Growth rate is for the 1978–90 period.

[d] Growth rate is for the 1977–90 period.

	Input oriented					Total	
Year	Agricultural chemicals	Machinery	Veterinary & pharmaceutical	Plant breeding	Postharvest & food processing	Current	Real
	(millions of current dollars)					(millions 1980 dollars)	
1960	9.7	75.9	6.0	5.6	80.0	177.2	511.9
1965	63.0	86.9	23.0	8.8	123.1	304.8	700.1
1970	126.0	89.1	45.0	26.3	206.1	492.5	839.0
1975	176.0	138.0	79.0	50.0	273.1	716.0	917.6
1980	390.0	287.0	111.0	96.7	456.1	1,340.8	1,340.8
1985	758.0	304.5	159.0	179.3	801.1	2,201.9	1,574.4
1990	1,031.0	360.5	245.0	314.4	926.9	2,877.8	1,544.6
1991	1,077.0	381.9	276.0	342.0	962.7	3,039.7	1,557.1
1992	1,123.0	394.0	306.0	399.7	1,088.0	3,310.7	1,648.0
	Annual growth rates (percent)						
1960–92	16.0	5.3	13.1	14.3	8.5	9.6	3.7
1960–70	29.3	1.6	22.3	16.7	9.9	10.8	5.1
1970–80	12.0	12.4	9.4	13.9	8.3	10.5	4.8
1980–92	9.2	2.7	8.8	12.6	7.5	7.8	1.7

SOURCE: Alston, J.M. and Pardey, P.G., *Making Science Pay: The Economics of Agricultural R&D Policy*, American Enterprise Institute Press, Washington, DC, 1995 (forthcoming).

the share of total private sector research directed toward agricultural machinery dropping from 43 percent in 1960 to less than 12 percent just three decades later. Two of the more significant growth areas were plant breeding and veterinary and pharmaceutical research. Spending on agricultural chemicals research grew the fastest and now accounts for about one-third of total private agricultural research.

Overview of Funding Patterns

These data point to a dramatic shift in the pattern of publicly and privately conducted agricultural research in the United States over the past two or three decades. In summary, both the private and public sectors have expanded their annual investments in agricultural research, but private sector agricultural research has expanded more quickly. Within those broad categories the mixture of activities has changed: not every element has grown at the same rate. Among the changes in support for agricultural research, perhaps the most significant is the declining share provided by state governments. State government support for SAES has been stagnant during the 1990s, a change which has been offset by rapid growth in fees and sales, and industry support, combined with some growth in federal government support. At the same time, the nature of federal government support has changed, with an increasing emphasis on competitive grants and a dwindling role for formula funds. A persistence of such patterns of change seems likely, and would have major implications for the structure, conduct, and content of public research at both the state and federal levels. Of course, the rate, as well as the direction, of change, is critical.

GOVERNMENT ROLE IN AGRICULTURAL RESEARCH

Government action is warranted if it is believed that the benefits of agricultural research will exceed the costs. The best kind of intervention is the one with the greatest net national benefit. In the case of agricultural research, the unfettered workings of the free market produce too little research and not enough agricultural scientists. What should the government do? Government production is only one of several options. Government research funded by general government revenues is not obviously the best policy in all cases, but it is by far the dominant element of U.S. government response to a private sector underinvestment in agricultural research. High rates of return to this investment justify the government intervention and testify to a substantial persistent underinvestment.

The mix of agricultural research (in terms of the types of research being undertaken), and the way funds are obtained, disbursed, and managed, are also questionable. Questions can reasonably be raised about the distribution of the total between the intra- and extramural alternatives, and about the incentives within USDA's administration of the two programs. Questions can also be raised about the processes and procedures used to allocate research resources within the two broad programs. Of the extramural funding through CSREES, very little is allocated according to economic, or even scientific, criteria. Only one-quarter of the total extramural funding goes to competitive grants. More than half of the extramural funds are distributed among states by formulas based on their values of agricultural production and rural and farm populations, essentially political criteria that are unlikely to yield the maximum social payoff to the investment. Other extramural funds are allocated according to other political criteria, through the Special (earmarked) Grants program.

Financing arrangements, as well as spending patterns, can be improved. The contributions by state governments have been declining as a share of the total. And while private sector research and industry contributions to public sector research have been rising, the general taxpayer still bears the brunt of the burden.

Principles for Intervention

The optimal intervention by the government, aiming to reduce the distortions arising from

inadequate private sector incentives for agricultural research, would seek to:

1. optimize the total investment in public sector agricultural research, and the mix of research, while minimizing the attendant problems of "crowding out" private research;
2. minimize the cost of raising the revenues to finance public sector research by using the least-cost sources of funds;
3. organize public sector research institutions so that they can conduct research in the least-cost way, with a minimum of wasteful replication of facilities and programs;
4. allocate and use research resources efficiently among programs and projects (that is, according to economic criteria, not political criteria), minimize transactions costs and administrative and bureaucratic overhead, and allow decentralized decision-making where effective incentive mechanisms are possible.

Respectively, these four principles relate to economic efficiency of research in terms of (a) the total funding, (b) the sources of funds, (c) institutional organization, and (d) resource allocation and management. This section considers these four elements of research policy with a view toward identifying possible changes that would lead to greater economic efficiency.

Total Funding for Agricultural Research

Agricultural research institutions and policies have evolved considerably since their inception. The public sector U.S. agricultural research enterprise is now big business—worth more than $2.6 billion per year. Correspondingly, private sector investment in agriculturally related research grew to total $3.3 billion per year by 1992. In spite of the government's efforts, there is still too little agricultural research being produced. A significant increase in federal funding, or federal government action to stimulate increased funding by either state government or industry, seems to be warranted. Unlike other agricultural programs in the farm bill, which involve a net drain on the economy, agricultural research is a socially profitable thing for the government to do. Concerns about the budget should not crowd out agricultural research.

In relation to total funding, prospects for expanding total federal funding for agricultural research seem gloomy, and it might not be the most economic way to address the sustained underinvestment. Hence, alternatives are discussed for using federal resources to mobilize greater supplementary funding from other private and government sources.

Financing Strategies

Under the present policy, a mix of federal and state government funding is used to support agricultural research conducted by SAES. In addition, federal and state governments conduct separately administered programs of research. The primary source of funding for these expenditures is the general tax revenues of the federal and state governments—an expensive source of revenues[12] (10). Industry funds garnered through tax incentives, matching grants, or from checkoffs may be less expensive, fairer, and politically more sustainable when used to finance certain types of research in order to achieve an expanded total public sector research budget[13].

Agricultural research may be a public good, accessible and potentially beneficial to all, but this does not mean that everyone in the nation benefits and it does not mean that everyone in the nation should pay. Both fairness and efficiency are promoted by funding research so that, as

[12] Recent studies have shown that it costs society more than a dollar to provide a dollar of general taxpayer revenues to finance public expenditures. The U.S. evidence indicates that a dollar of government spending on agricultural research may cost society between $1.07 and $1.25 when the market problems induced by taxation are taken into account (10).

[13] There are two basic types of checkoff programs: voluntary and legislated. Voluntary checkoffs involve industry members funding certain activities by agreeing to contribute funding for a common purpose. Legislative checkoffs involve the passage of legislation by a government entity (state or federal) requiring certain persons (such as farmers) to pay assessments on marketing or some other act of a particular product or service.

much as possible, the costs are borne in proportion to the benefits.[14] This can be encouraged by choosing funding arrangements that reflect the geographic focus and the commodity orientation of the research. Thus, different agricultural research programs and projects call for different funding arrangements. In particular, a greater use of private sector funding through such vehicles as commodity checkoffs and a greater use of multistate (but subnational) regional or commodity research programs is suggested. The federal role in both instances may be to develop the institutional arrangements, to provide incentives such as matching grants, or both.

Industry contributes very little directly to U.S. public sector agricultural research; it is mostly funded by the general revenues of federal and state governments.[15] This situation should change for three reasons. First, industry funding is a potential complement to other sources of funds which, as a practical matter, are likely to continue to leave total funding inadequate from the viewpoint of both the industry and the nation. Second, from the point of view of raising funds in the least-cost way, mechanisms such as commodity checkoffs are likely to provide a relatively efficient (and fair) tax base. Third, in relation to allocating the funds efficiently, industry funding arrangements can be organized to provide incentives for efficient use of checkoff funds and other research resources.

Checkoff programs, as a major form of agricultural research funding, can be a practical reality. In 1985, the Australian federal government introduced legislation that provides for groups of commodity producers to establish research funds based on a checkoff (industry levy), which the government will match up to 0.5 percent of the gross value of production (GVP) of the commodity. These arrangements (revised in 1989) have been very effective in increasing total resources available for agricultural research. Indeed, for several commodities the 0.5 percent constraint on matching funds is binding; the research institutions are spending 1 percent or more of GVP (13).

Checkoff funding is clearly applicable to research on a particular commodity. By definition, this is not basic research. Similarly, checkoff schemes tend to be less applicable to research that affects multiple commodities and research that applies to particular factors of production or that has an environmental focus, but they need not be. However, these issues notwithstanding, commodity checkoffs could be used more extensively to support the significant proportion of research that can be identified with a well-defined commodity (or other) interest group. Some of these mechanisms are already in place in the United States but are relatively underused in the sense that only a small fraction of total research resources are generated in this fashion, and the checkoff funds are directed mainly toward market promotion.

The federal government could encourage a greater use of such funds for agricultural research by providing matching (or more than matching) support for programs funded using industry checkoffs. When a combination of industry levy funds and general revenues is used to finance public or privately executed research, there is a clear case for government involvement in the administration, management, and allocation of those funds to ensure that the public interest is adequately considered. It is important to understand that industry checkoff funding is not to be regarded solely as a producer "self-help" arrangement, that is, producers collectively funding research on their own behalf and to serve their own ends. Consumers and taxpayers are affected by, have an interest in, and should be involved in such enterprises as much as produc-

[14] Incentive problems in agricultural research arise from inappropriability of benefits and free-riding, and may be serious unless some way can be found to ensure that beneficiaries share appropriately in research costs. Hence, a criterion for efficiency, as well as fairness, is to whom the benefits accrue.

[15] The comments here pertain more to the farm production sector than to the input supply and post-farm agribusiness sectors which do fund and execute significant amounts of research.

ers. Producer-dominated boards allocating such funds are likely to direct research resources toward work that benefits a narrower set of interests than may be socially optimal. In addition, there still may be incentive problems if, within the group of producers and consumers of a commodity, there are different distributions of benefits from different research programs (for instance, producers from a particular region prefer research specific to their own situation, which may not benefit certain other producers).

What seems to be equally or more important, to secure industry support for this type of program, is an assurance that funds raised through checkoffs would not crowd out other federal or state research funding. If the use of commodity checkoffs would not yield an increase in total research funding, there might be some efficiency gains in terms of lower social costs of funding and greater efficiency of research resource allocation—but much diminished gains compared with a situation where the checkoff funds were additional. This is particularly so since checkoff funds are liable to be spent on relatively applied work, where the social returns may be relatively low. If the checkoff funds were not additional, some loss of efficiency might be associated with the effective diversion of funds from more basic to more applied research.

Research Organization

The appropriate regional and institutional structure for organizing research programs ought to vary according to the nature of the research. Some issues are clearly national issues and are appropriately addressed by federal programs. But the federal government can choose whether to address an issue using federal funds in federal research institutions, or in state organizations (or, for that matter, in private organizations), or by using incentives to encourage state organizations to take joint action.

Institutional Structure

In the land-grant system, SAES are substantially and physically integrated with colleges of agriculture (and, in many cases, extension agencies). This institutional structure was initially justified on the grounds of "complementarity" between research and teaching and extension. Although it is still a widely cited rationale for the continued support of the land-grant system, the precise nature and magnitude of these complementary effects is not always as clear as may be desirable. In any event, it is an open question whether the current number and structure of land-grant colleges, which has changed little over the years, is optimal for today. If we were designing the land-grant system today, from the ground up, for conditions in the twenty-first century, the results might be very different.

Serious study is warranted into whether economic efficiency criteria justify a land-grant college for each and every state (from a federal, if not a state perspective). It may be economic, for instance, to consolidate some college programs and, perhaps, some research programs among states, given that students are much more mobile and communications are much better these days than they were when the land-grant colleges were first formed. Similar questions can be raised about the organization of extension. Sources of supply for agricultural extension services are expanding rapidly. This factor, coupled with accelerating improvements in communication and information technologies, and better-educated farmers, raises similar questions about the cost-effectiveness of investments in agricultural extension services in the current organizational structures. These issues are well beyond the scope of this present study. The Board on Agriculture is currently conducting a study of the Land Grant University System, considering both research and teaching functions and their interactions. That study is expected to document in detail the nature of the interactions between the different functions and the evolution.

To facilitate some investigation of the potential roles for institutional alternatives, work is also under way to review the institutional structures in other countries, including Australia, the Netherlands, and the United Kingdom. In each of these countries there have been important recent changes in the administration of agricultural research, including issues of financing, organization, and management. Although none of those countries has ever had an arrangement like the U.S. land-grant system, combining research, teaching, and extension, their experiences of change may provide some lessons for the United States.

Regional Issues

Research spillovers, where results from one state's research are adopted in another state or overseas, are important. Individual states may not be able to capture economies of size and scope in research programs that pertain to larger jurisdictions. As a consequence, state-level arrangements are often inadequate. The intramural work of the USDA laboratories can often be seen as an effort to find solutions to problems that touched several states, but were beyond the research capabilities of individual states. At the same time, federal funding of *national* programs is not always the right policy for addressing underinvestment in research issues that involve multiple states.

Congress and USDA have also adopted a variety of approaches to encourage multistate cooperation in agricultural research. Support for regional research in SAES has been provided both on a formula basis, as earmarked funds, and more recently (as in the regional centers supervised by the Alternative Agricultural Research and Commercialization Board, created in the 1990 farm bill) on a competitive basis. The most concrete development was the institution of the nine regional research laboratories under the Bankhead-Jones Act in 1935 to study specific crops, livestock, and resources issues, and the four regional research laboratories introduced in 1938 to study new industrial uses for agricultural products. To many those developments might appear to have been driven as much by political and, perhaps, scientific factors as economic ones.

Research Funding Decisions, Resource Allocation and Management

The current set of institutional arrangements apportions research funds among alternative research-executing agencies in ways that have little economic foundation. High measured rates of return notwithstanding, a sizable share of the potential benefits from the agricultural research enterprise may have been wasted in inefficient resource allocation.

Roles for Economizing

Some would say that the system has worked very well (high reported rates of return testify to that) and, by implication, that we should not spoil a good thing. There is some truth in that. The public sector agricultural research system has achieved a great deal, and it would be undesirable to change it in ways that would diminish its capacity to contribute to the economy into the future. By the same token, the fact that it has done well does not mean that it could not have done better. Moreover, having done well in the past might not guarantee continued future success, especially considering recent trends in the evolving structure and management of the system that, if allowed to continue, may threaten its future effectiveness.

These concerns include, in particular, the rising politicization of research, including the rise of earmarked funds and declining state-government support. The rapidly changing economic environment in which the research system finds itself is also relevant in this regard. Things that worked in the past may not work in the future. The public sector may need to reconsider and revamp the way it goes about its business.

Allocating scarce research resources is an economic problem. In the system as it stands, too little use is made of economic analysis, economic incentives, and the economic way of thinking about problems. The current system emphasizes processes and politics, the inputs side, and pays

scant attention to actual performance, the outputs side. There is a notable lack of any systematic attempt to undertake economic evaluation studies on agricultural research investments as an integral part of the resource-allocation process. Resources are allocated according to ad hoc approaches that may simply serve to reinforce prior prejudice.

Economic Criteria

It is very important to institutionalize processes that establish and enforce an economic efficiency criterion as the primary (preferably sole) basis for allocating research resources and for evaluating research performance, so that research resources are freer to flow flexibly, according to economic criteria, to achieve the most good. A simple, singular, economic efficiency objective coincides with the rationale for public sector research.[16] Resolving a simple objective also allows the development of simple and clear criteria for making decisions about how to allocate resources, about how to evaluate the outcome from research and, perhaps, about how to reward effort.

Earmarked Funds

The current system of formula funding is uneconomic and it is not obviously fair. However, it may be superior to earmarked Special Grants. Special Grants have been rising relative to other components of the research pot. If these earmarked grants do not crowd out other uses of the funds, they may not be as bad as if they compete for funds with projects that are justified on merit. Indeed, if they are additional funds, Special Grants might even be a profitable use of society's resources—but that seems unlikely. On the negative side, much of what is done in the name of Special Grants is of questionable intrinsic merit, and it is visible "pork" that looks bad and taints an otherwise, at least potentially, "clean" portfolio. It is not clear what can be done to reduce the politicization of research. One possibility is to increase the emphasis on demanding demonstrated benefits assessment as a criterion for funding. Another is, through regular formalized system reviews, to systematically expose the costs (or their orders of magnitude) of the elements that cannot be justified on merit.

Competitive Grants

Competitive grants, discussed in chapter 3, have a great deal to recommend them as a way of allocating public sector research resources. However, competing for grants is hard work and expensive, and if competitive grants are to deliver the promised benefits of greater allocative efficiency, they have to be allocated according to efficiency criteria. The same arguments can be applied to USDA's intramural research efforts. There is no reason why non-SAES organizations should not be allowed to compete for extramural funds, as in the NRICGP. Likewise, there seems to be no good reason why such a large share of the USDA agricultural research budget should be quarantined from competition. ARS will clearly be superior to SAES in some research areas, and vice versa; in some other areas they should collaborate.

Such decisions could be based on economic considerations rather than precedence. In general there could be more open competition, greater public scrutiny, and greater accountability for the public sector research effort. This change could be conducted in terms of the economic impacts of the research. It is not obvious what implications this more open competition would have for the balance of funding between the intra- and extramural research programs, but it would be expected to enhance the total net benefits through more efficient use of the funds.

[16] Although research ought to be directed according to economic efficiency considerations at the strategic or programmatic level, different criteria may be more applicable at the level of individual projects or individual scientists. Research within broad programs may be best directed according to well-structured and well-executed peer review. At that level, the critical issues may be scientific merit and technical considerations, such as the probabilities of research success and the likely lags involved in the research, more than the other economic variables.

Alternative arrangements could be instituted to reduce reliance on politically based Formula Funds and Special Grants for SAES, and to open up the USDA intramural funds for competition, thereby strengthening funding for competitive grants. But this must be subject to some caveats. Proposals ought to be subject to review based on the sole criterion of the expected economic benefits. A poorly administered and corrupted system of competitive grants could easily be worse than the antiquated, inefficient, and inflexible system of formula funding.

Transactions Costs

Some have argued that the transactions costs involved in competitive grants programs—in terms of the costs to individual scientists of preparing proposals, and reporting to granting bodies, and the costs of evaluating the proposals and deciding which ones to support—are so high that the programs cannot be economic. That charge could be accurate, but relevant alternatives must be compared, and on a comparable footing.

Every method of allocating research resources is bound to involve four types of costs: (a) information costs (the costs of obtaining relevant information on the benefits from different types of research projects, on which to base decisions); (b) other transactions costs (the costs of applying for grants, managing them, and administering them); (c) opportunity costs of inefficient resource allocation, due to research resources not being used in the projects and programs with the highest social payoff; and (d) "rent-seeking" costs (costs of resources being spent wastefully attempting to cause a redistribution of grant resources).

Different research resource allocation processes will involve different amounts of particular types of costs. For instance, through the proposal process, competitive grants generate information about research alternatives for decision makers. Although they may lower the cost of certain types of information, they also involve relatively high transactions costs. They might also involve relatively high rent-seeking costs (say, of scientists lobbying for their programs to be supported). However, these additional costs may be justified if competitive grants lead to a lower overall social cost, because they reduce the cost of resource misallocation. On the other hand, formula funds involve relatively high resource misallocation costs, which get higher the longer a formula stays fixed (since circumstances change) and relatively low transactions costs. This is not to say the transactions costs are zero, or that the rent-seeking costs are zero with formula funds (there is a fair bit of bureaucracy associated with the administration of the funds; the formulas do or, at least, may change from time to time). Earmarked funds may involve the greatest rent-seeking and resource misallocation costs, but they may also involve relatively small transactions costs. In short, the full costs should be considered when comparing research resource allocation procedures. Competitive grants are *relatively* efficient, but that is based primarily on a perception that the alternatives have involved very significant opportunity costs arising from resource misallocation.

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